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EDITORIAL

HEVEA BUDWOOD

THE increasing interest of the planting community of Ceylon in the improvement of yields of rubber by budding has led to a demand for budding material. Unfortunately the value of propagation of *Hevea* by budding has not been fully appreciated in Ceylon until recently and, in consequence, we are somewhat handicapped by the fact that there are no locally-grown mother trees which have been proved by experiment to transmit their high-yielding characters by means of their budwood.

The attention of readers of *The Tropical Agriculturist* is drawn to the difference between proved and unproved material. Budwood and budded stumps from certain Dutch clones, such as those from Tjirandji, Bodjong Datar and A. V. R. O. S., are proved material. The budded clones of these mother trees have been tested by tapping for some years and the results have shown that budwood from these clones is satisfactory. In the selection of these clones a number of others, of which the mother trees were presumably high-yielders, has been discarded. Prospective buyers of budwood or budded stumps of these clones would do well to ask for guarantees that their purchases are genuine. When the buddings are a few years old, clones may be distinguished by certain vegetative characteristics and the possession of a guarantee would be valuable in the event of a misrepresentation.

The purchase of unproved budwood entails some risk. Unproved budwood is obtained from mother trees which have been selected on their yield of rubber. A proportion of such mother trees may be expected to give high-yielding clones but, on the other hand, a proportion will probably give unsatisfactory clones. It is not suggested that local unproved material should be avoided. If the buyer appreciates that it is unproved he can make arrangements accordingly and plant up his area in such a way that, should one or more of the unproved clones eventually be unsatisfactory, such clones might conveniently be removed. It is obvious, however, that unproved material should not cost so much as proved material. In addition, a buyer of budwood from unproved trees should be furnished by the vendor with a certificate to the effect that the budwood is from a certain mother tree, together with yield records of the mother tree up to the date of purchase and with a promise of records of the clone when the results of test tappings are available. The provision of such records should not be difficult for a *bona fide* vendor and would enable the purchaser to take advantage of subsequent information as soon as possible.

In regard to the cost of budwood it is not the wish of the Department of Agriculture to undersell private agencies. It is appreciated that owners of commodities for which there is a strong demand should be able to reap the advantages of their foresight. With the advent of competitors and the increased local supply of budwood prices are bound to fall to an economic level. As an indication of the relative value of proved and unproved budwood it may be stated that the price of budwood which will be available at Peradeniya in October of this year has been tentatively fixed at Rs. 15/- per yard for imported proved clones and Rs. 6 per yard for H2 and other unproved clones selected from trees owned by the Department of Agriculture, all of which are being tested experimentally at Iriyagama.

CITRUS

THE PRESENT POSITION OF ORANGE AND GRAPEFRUIT CULTIVATION IN CEYLON WITH SUGGESTIONS FOR ITS IMPROVEMENT

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1. PRESENT POSITION

OF the publications, particularly in recent years, on the cultural requirements of the orange and grapefruit, few if any, are entirely applicable to Ceylon, and it is difficult for the would-be grower of these fruits in this country to ascertain firstly, the type or the types suitable to his elevation, rainfall and soil conditions, and secondly, the subsequent methods of cultivation whereby an investment in growing either of these fruits has a fair chance of proving remunerative in a not too distant future.

Dealing first with the orange. The Empire marketing Board in a recent publication by their Statistics and Intelligence Branch (E.M.B. 13) shows the principal countries of orange production, in order of numerical importance, to be Spain, California, Florida, Japan, Italy, Brazil, Palestine, Algeria, N. S. Wales, Paraguay, South Africa and Porto Rico. The production varies from 1,117,000 tons for Spain to 13,000 tons for Porto Rico, and there are thirty three other countries producing or exporting amounts under 12,000 tons of these fruits per annum. It may be observed here that 99 per cent. of the world's orange production is found between latitudes 20° and 40° in both northern and southern hemispheres, and only 1 per cent. between latitudes 20° north and south of the equator, the latter applying to small productions of this fruit in Jamaica, Costa Rico, Honduras, India, Bahia, Queensland, the Society Isles, Columbia, Ecuador and Tropical Africa.

It would appear from this that Ceylon, being situated between latitude 6° to 10° north of the equator, does not come within a normal orange growing belt, and that the success of orange cultivation on any large scale within her latitudes is problematical. There are however certain

factors which counteract this apparent disadvantage to a considerable degree, and these Ceylon possesses in its highland areas with their varying conditions of rainfall and temperature and of soil. The fact that Jamaica under conditions similar to those of the low and mid-country of Ceylon is increasing its annual production of oranges (some 796 acres being devoted to this crop during 1927-28) indicates that the cultivation of such in Ceylon should, if a suitable type or variety of fruit is obtained, and proper cultural methods applied, be successful.

2. STOCKS SUITED FOR THIS COUNTRY

The common orange of Ceylon, especially when not cultivated with some care, yields a fruit often coarse, thick skinned, and invariably green when ripe, due principally to a tropical environment combined with a too heavy rainfall and lack of proper drainage and cultivation. As is the case with most other good fruits, successful propagation of the orange and grapefruit is best attained by means of budding and grafting. The impression however that a budded or grafted tree must of necessity be superior to a seedling is wrong, as much depends on the quality of the fruit tree from which the bud or graft is obtained, its suitability to the stock on which it is used, the hardiness of the stock, its disease resistant qualities, and its adaptability to the scion for which it is to be used. Hardiness, as generally understood, is the power of the stock to resist cold conditions, but in this case a stock possessing qualities to resist heat and moisture and the lack of any dormant season, is called for.

Small importations of budded or grafted oranges, mostly of the Washington Navel variety, have been made by Ceylon residents for many years past, and the selection of this type is a wise one. The attention paid to the question of on what stock these Navels are budded is rarely, if ever, enquired into, yet with the varying conditions of climate and soil existing in Ceylon, it is probably the most essential point to keep in mind.

The most hardy and vigorous stock suited for these conditions in respect to both orange and grapefruit should be tried in Ceylon, and these are as far as present experiences go, the sour or Seville orange, the pumelo, and the Nataron variety of the lemon. The sweet orange was at one time a universal stock in Florida, California, the Mediterranean countries and Australia, as it has a well developed root system and rapidity of growth, but owing to its susceptibility to *Mal di goma* its use has been largely discontinued, and the pumelo and sour orange have been

utilised. The latter is of particularly robust growth, probably the most vigorous species of the genus; the root system is well developed, and it is believed to be immune from root rot. Hume, in *The Cultivation of Citrus fruits* states "It is safe to say that over seventy-five per cent. of the world's output of citrus fruits is produced by trees on sour orange stock."

In Ceylon, both sour orange and pumelo are available and appear to meet all the requirements of a perfect stock under the conditions experienced at Peradeniya, where both soil and drainage are extremely poor, and the Nataron thrives almost as well.

The general conclusions arrived at in experiments undertaken at Peradeniya are that the sour orange and pumelo are stocks best suited to the low and mid-country of Ceylon under moist conditions, whilst the sour orange and Nataron should prove best for up-country and semi-dry regions, with Nataron as preferable for the dry regions proper, under irrigation. The indigenous *Atalantia Missionis*, the "Pamburu" of the Sinhalese and "Kuruntu" of the Tamils should also, in the writer's opinion, prove an excellent stock for dry and semi-dry districts, as it is a seemingly disease-resistant relative of the orange; but this tree, like most of the indigenous *Rutaceae* is a native of the dry regions, and does not grow well under the moist conditions of Peradeniya, and little can be made of it here.

Additional stocks that are under trial in the Botanic Gardens at the moment include *Citrus Hystrix*, a local semi-wild species, *Citrus megaloxycarpa* a locally-planted species but not yet found wild, and *Citrus mitis*, which is reputed to be disease-resistant. It is anticipated that these will afford additional resources in stock supplies to meet the varying requirements of the different parts of Ceylon at a later date.

3. ORANGE GROUPS AND VARIETIES

Of the oranges generally in cultivation, four main groups are recognised, the Spanish, the Mediterranean, the Blood and the Navel, and of those so far tried in the Island the Navel predominates. With the types of stock available and the varying conditions experienced in the Island, selections from other types might well be tried with advantage. It is well to remember however that the best orange growing districts in Ceylon are those of medium elevation possessing moist to semi-dry conditions.

Of Spanish oranges a wide selection is available and varieties such as Boone, Enterprise, Non-pareil and Parson Brown should be suitable, Enterprise being a seedless

variety. Of Mediterranean oranges, good varieties are Bessie, Exquisite, Lue Gim Gong, Majorca, Pineapple and Valencia and small consignments of this group are already on trial in Ceylon. The Blood oranges are generally considered of high quality and possess few seeds, though the fruit is generally smaller than oranges of the other groups. The varieties probably best suited to Ceylon would be Ruby and St. Michael. The Navel group of oranges are generally recognised by the peculiar umbilical formation on the apex of the fruit and it is this type that is generally imported by Ceylon residents. The best varieties of this group for general cultivation are the Washington Navel, Surprise and Sustain, the latter and Washington Navel being seedless, and for Ceylon the Washington Navel would most probably not be beaten.

4. GRAPEFRUIT VARIETIES

In respect to grapefruit cultivation, low-country to mid-country districts of the Island are more suitable than higher elevations. It has been mentioned before that medium elevations are requisite for the best results in orange cultivation, but a warmer temperature and a larger amount of moisture are generally necessary for grapefruit, though sheltered pockets up-country are also to be recommended.

The stocks suitable for this type of citrus are again the sour orange, the pumelo and Nataron. Buds established on these stocks have made vigorous and shapely growth, and all the three are to be recommended, provided good drainage is afforded the plant. The additional species already mentioned may possibly furnish other useful stocks suited to the various conditions. Minor experiments only have been laid down so far with the object of determining the value of a certain stock for a certain variety of citrus. Until a greater variety of material in the way of budwood is available experiments cannot well go further. The grapefruit is a comparatively recent acquisition to Ceylon, though the two original trees introduced to the gardens date back to 1897 and others at the Experimental Station, Peradeniya to 1910. It is from these trees and from the tree at Kegalle park that the budwood for experiments to date has been obtained.

Among favourite varieties of grapefruit at the present time of which plants have of late years been imported for trial in Ceylon are Duncan, Foster, Marsh's Seedless, McCarty, Pernambuco, Triumph and Walters. The first three named do well in Jamacia and Porto Rico soils, and

on observations made to date the Duncan and Marsh's Seedless appear suitable types with which to persevere in Ceylon.

5. PROPAGATION AND PLANTING

Both the orange and grapefruit are now propagated chiefly by means of budding, for as mentioned before, the fruit of seedling trees cannot be depended on to result in uniform specimens, and numerous different types of fruit will invariably be observed in even a small group of trees. But variation seems a common phenomenon in the genus *Citrus*.

Good seedlings of the sour orange, pumelo or Nataron for stock purposes are the first necessities and two points should be observed, firstly, that the seed is obtained from fruit thoroughly ripe, and secondly, that the fruit is from perfectly sound and healthy trees. Only plump heavy seed should be selected, the lighter seed being discarded; the seed should not be allowed to dry, and should be washed before planting.

Seed beds should be prepared in a sheltered position with good soil and ample drainage. The beds should be well dug and the soil pulverised, adding a fair proportion of cattle manure and removing all coarse stones, leaving a good friable surface in which to plant. The width of the seed bed should not exceed four feet, this allowing attention in weeding and cleaning without trampling the beds. Seed should be sown in rows one foot apart, and one foot between the rows if for direct budding, a procedure carried on quite successfully at Peradeniya, but seed sowing at two inches apart in the row and six inches between the rows is generally adopted if the seedlings are to be transplanted before budding, the latter system being the best generally. The beds should after sowing of the seeds be shaded in the mid-day hours for the first few weeks and should be watered only when dry, the bed surface being frequently stirred to allow ample aeration.

Transplanting should take place when the seedlings are approximately eight inches high, these being then planted out in rows at from fifteen to eighteen inches apart and the same distance between the rows. Particular care will here be required to ensure as little check as possible to the growth of the plants and that the strongest and best of the seedlings only are used, all weak and unhealthy plants being rigorously discarded.

Budding can be undertaken at a point five to six inches above ground level when the seedlings have attained the thickness of a lead pencil. The best season for budding

varies with the different localities, but in general those months with light to moderate rainfall give most satisfactory results, or in other words avoid budding during the periods when heavy monsoon rains are experienced, and in times of drought.

When selecting budwood, all angular shaped shoots should be avoided and buds should be obtained only from well matured round wood of the previous season's growth. It is perhaps unnecessary to add that budwood should be taken only from those trees showing healthy growth and whose good bearing qualities and flavour of fruits are known. As bud variation occurs in both orange and grapefruit the practice of obtaining budwood from young trees that have yet to fruit, even though they may have been budded from good parent trees, is not recommended.

The rectangular patch, the T-budding and the inverted T, are satisfactory modes of budding for both oranges and grapefruit, and the bud-shield should be half an inch to three quarters of an inch long. The bud when cut from the budstick should be immediately inserted in the cut in the stock, every care being taken not to injure the cambium surface of the bud, and the bud union then wrapped fairly firmly with waxed cloth. After ten or twelve days the wrappings should be loosened and after three weeks the wrappings can be removed. If the union is successful the stock should be shortened to allow its vitality to be transmitted to the dormant bud and hasten its development. As the new bud develops the top of the stock will eventually die back to the point of junction with the scion and should then be cut away with a sharp knife and the cut treated with a preservative.

Transplanting of the budded plants to permanent quarters can be undertaken at twelve months from budding. Showery weather should be selected for this operation. Good holes, three feet by three feet should be prepared and refilled with a mixture of good soil and well rotted cattle manure, and plantings made at distances of 15 to 20 feet apart for oranges, and 20 to 25 feet apart for grapefruit. Care should be taken not to insert the young plant in the bed too deeply and it is better to plant high to allow for sinking of the bed, the crown roots appearing just above ground level. Shading and regular watering, should the weather be dry for the first few weeks from planting, must be made. The staking of the plants at this junction is important for the eventual shaping and development of the tree, and stout stakes should be used.

As the bud grows a standard habit should be encouraged and all side growths should be rubbed off as they appear. As the young buds reach the desired height, that is 36 inches from the ground, they should be topped by cutting back to 24 inches from the ground to allow side branches to develop. The topping will result in several shoots being thrown out and four or five of the strongest should be selected, and the rest removed.

6. CULTIVATION

As a general rule citrus will do well in most soils, but a heavy soil through which water does not percolate easily, or which is constantly moist, is a decidedly unsuitable soil for both the orange and the grapefruit. Good drainage is undoubtedly one of the most essential requirements of these plants. Depth of soil is another necessary requirement for both types, each being a more deep-rooted subject than is generally imagined and possessed of a strong taproot. A shallow soil is unsuitable as the trees fail to develop and will stagnate at an early age, and soil at least 36 inches in depth is required. A very light sandy soil should similarly be avoided, especially for grapefruit, since with a deficiency of plant food exceptionally heavy quantities of manure would be required and cost of production would be excessive.

Light soils that have become salt owing to irrigation without proper drainage are injurious to most plants, and especially so to all species of *Citrus*. Though Ceylon soils are usually poor the composition varies greatly; that in the sea coast areas being generally of a gravelly to sandy nature with a large proportion of laterite, whilst those inland are mostly of reddish clay with a proportion of laterite. Up-country soils are generally of a more loamy character with a varying proportion of humus, whilst soils of the Jaffna peninsula are more often of a hard clayey nature. The semi-dry regions of Ceylon provide varying soils, in some places hard and poor, and in others deep and black.

Up to date cultivation in the direction of deep trenching and judicious manuring should render the majority of Ceylon soils suitable for citrus cultivation. Rainfall is an important factor but experiences in this respect as to the requisite amount varies greatly, as quite useful crops of the Washington Navel orange have been obtained without irrigation in districts receiving only 45 inches of rain per annum whilst on the contrary, good crops are obtained at Rangalla with 168 inches annual rainfall. The

difference is remarkable, but the latter trees were observed to be planted on fairly steep land which doubtless counteracted to a large degree the results of the high rainfall.

Given a choice however of locality and conditions for first rate orange cultivation in Ceylon, a site between an elevation 1500 feet to 5000 feet with gently sloping land of alluvial soil at least three feet deep (the deeper the better) combining thorough drainage, a rainfall of 45 to 75 inches, and protection from strong wind, would be ideal.

For grapefruit cultivation the elevation most suitable would be from sea level to mid-country and should not exceed 4000 feet unless exceptionally well protected. A site should be selected with deep soil on sloping land with ample drainage, and a rainfall of anything over 60 inches, equally distributed, but with a rainfall of over 120 inches per annum a good system of drainage is imperative.

The budded plants having been established in permanent quarters as described under the head propagation and planting, subsequent methods of cultivation, manuring, pruning, etc., remain to be considered. In respect to small groups of a few trees planted as is generally the rule within the compound area of the ordinary Ceylon resident, catch crops of vegetables could be raised for the first few years if the area immediately surrounding the newly-planted trees is not encroached upon, but this should cease on the trees attaining the age of approximately 3½ years from planting, and earlier if the trees are observed to be making very rapid growth. Where groves are planted on estate commercial lines the sowing of cover crops best suited to the locality is advisable. This obviously not only shades the bare land from the sun but when these crops are forked in humus is added and the condition of the soil greatly improved. In this case also an area around the planted trees of at least 3 feet from the stem should be kept open to allow periodical manuring and treatment of the prepared beds.

7. MANURING

Citrus plants have no recognised dormant season in Ceylon and the roots are active throughout the year and have consequently to be fed. The correct manuring principles to adopt in regard to both orange and grapefruit have yet to be exactly ascertained, but where organic manures are available these should be applied in view

of the lack of humus generally in Ceylon soils. Manuring, by application of well-rotted cow manure, should preferably be undertaken twice annually once the trees begin to make headway; at the beginning of each monsoon, in May and in October; and mulched with dry leaves or grass at the beginning of each dry spell, at the end of January and the end of July.

Should cattle manure be available in insufficient quan tities, artificial manures should also be used. The necessary elements of plant food are nitrogen, phosphorus and potash, and the proportion of each to be added to the soil in any locality must necessarily vary with the quality and the composition of the soil in which the trees are planted. Two of the rules governing the adaptation of fertilisers to crops should here be borne in mind (*a*) for leaf and growth production a predominance of potash and nitrogen, and (*b*) for fruit production a preponderance of phosphoric acid and nitrogen with less potasht han the preceding. Very little information is available however with regard to the quantity of artificial manure that should be applied per annum to attain the best results, but as a general rule 600 lb. to 800 lb. per acre per annum should be suitable and sufficient for the trees in full bearing (the equivalent of 6 to 8 lb. per tree) smaller applications being made for the younger trees. Where soil conditions can be considered fairly normal, *i.e.*, not excessively poor a good general mixture is recommended by the Government Chemist, Peradeniya, as follows:

1 part Sulphate of Ammonia
1 „ Superphosphate
1 „ Steamed bone meal
1 „ Sulphate of Potash

this in addition to small quantities of well-rotted cattle or green manures. The application of such manures should be made preferably just before the rains by scattering by hand round the trees from a radius of 18 inches from the stem to 18 inches beyond the outside spread of the branches, and lightly forking the dressing in. If no rain is experienced, watering in of the manure should be undertaken early.

8. PRUNING

If properly headed at the planting stage as mentioned under propagating and planting, little pruning of the orange and grapefruit is needed later. The tree should not at any time be allowed to become too dense, such

being remedied by the removal of any undesirable branches at a young stage, the object in view being the formation of a shapely well balanced tree from which all dead, decaying, and injured wood is regularly removed. A well shaped citrus tree would be one with a main stem 2 feet high with not more than four or five main branches, and these branches should be allowed to carry just sufficient subsidiary branches to form the framework of the tree. All others are quite unnecessary and should be removed. All limbs should be properly spaced so that circulation of the air to the inside of the tree is possible. Too many branches mean crowded and weak growth resulting in crops of small fruit, and through lack of proper ventilation, liability to many diseases and pests.

9. CROPS

Normal budded plants of both orange and grapefruit should begin to produce fruits about the fourth year from planting and reach full production at the tenth or twelth year from planting. Crops will of course vary according to the type of tree, the health of the tree, and the cultural methods afforded it. The commercial orchards of other countries in respect to the Washington Navel orange show the crop, at the fourth year from planting and the first year of fruiting, to range from one or two fruits per tree up to thirty fruits, and at the tenth year from planting anything from 300 to 600 fruits; an outstanding specimen of some age would however produce well over 1000 fruits per annum. Whether such crops will apply to local conditions it remains to be seen, and much must depend on securing a suitable variety of orange at the outset.

Little information with regard to the probable annual yields of grapefruit in Ceylon can be given since the cultivation of this fruit is distinctly in its infancy here, but from the data available on crops of other parts of the world a yield of 350 to 500 fruits of average size per tree at maturity is generally considered a fair crop. Too much reliance cannot be placed at this stage, however, on such figures as likely to represent yields in Ceylon, and it is of importance that present and prospective growers of this fruit should endeavour to obtain accurate individual yield records of their trees for three or four years. The unit of production should be the individual tree, for with citrus, as with most other

good fruits, there are good yielders and poor yielders, though the variety grown may be of the best. The poor yielders are being maintained at a loss to the growers, and if proved material is available for subsequent plantings the returns of a plantation or garden would be greatly increased. A plantation as a whole may produce a satisfactory crop but if a proportion of the trees are not bearing well the production is obviously not as high as it should be.

10. DISEASES

On the subject of diseases the Acting Government Mycologist, Peradeniya, has supplied the following in respect to the four chief diseases of citrus in Ceylon:

1 *Citrus Canker* (*Pseudomonas citri*).—Citrus canker may be regarded as the most serious disease of citrus in Ceylon. It is more common in the wetter zones of the island, it having been shown that free moisture combined with temperature above 80°F supply the conditions most favourable for its spread. The symptoms of the disease are well known and consist of tan coloured corky eruptions in the middle of yellowish spots on green leaves, twigs and fruits, while in older stages cankers occur on twigs and stems.

Control Measures.—(i) The use of windbreaks of trees which prevent the dissemination of the casual organism by the wind and which prevent the whipping of the foliage, is of great assistance. (ii) In some instances new foliage growth may be stimulated during dry periods unfavourable to canker infection thereby escaping some infection. It has been shown that infection takes place much more readily on young leaves. (iii) Pruning out infected twigs and foliage during the dry season to eliminate sources of infection has been shown to be of value. (iv) Spray applications lessen materially canker infection and also serve to control other diseases. A very convenient spray compound is a proprietary lime-sulphur spray known as 'Sulfinette.' This liquid is convenient to use and does not clog the nozzles of spraying outfits. Spray programmes should be worked out for individual gardens. The spray employed should consist of a 1-2% solution of 'Sulfinette.' (v) It has been shown in Ceylon that canker often starts in the tissue injured by a leaf-mining caterpillar (*Phyllocnistis citriella*) and endeavours should be made to control the ravages of this insect. (vi) The use of resistant species and varieties is strongly recommended.

2 *Mildew.*—The orange mildew (*Oidium tingtanium*) causes some damage to young shoots of oranges. It is a white powdery mildew and can be controlled readily by spraying with the spray fluid recommended for citrus canker.

3 *Pink Disease* (*Corticium salmonicolor*).—Pink disease is a bark disease occurring on stems at or near forks and preventive treatment should aim at protecting these places. Periodical spraying, if applied to stems, will prevent the disease.

Branches on which the disease occurs should be pruned out at least 9 inches below the obviously affected tissue and the resultant wounds tarred. Provided that these sources of infection are removed, spraying will render the disease innocuous. It is not suggested that spraying should be undertaken for this disease alone, but that the stems should be sprayed for the control of citrus canker.

4 *Die-back*.—The cause of the die-back of citrus trees is not certain. It would appear, however to be associated with unfavourable environmental conditions particularly in regard to root development, root aeration and lack of cultivation. In India die-back of this type has been successfully overcome by digging trenches 3 feet deep, at a distance of about 6 feet from the trees, or, in plantations between the rows in both directions, and filling the bottom foot or so with stones, bricks and plant réfuse and the remainder with original soil mixed with manure. In the instance cited treated trees gave 30 times as much fruit as untreated. It is extremely likely that similar treatment will prove to be of value in the compact lateritic soils in Ceylon.

11. INSECT PESTS

Space allows only the briefest reference to the main insect pests of citrus in Ceylon and the Acting Government Entomologist, Peradeniya, has supplied the following information on the subject:

The most important local pests are plant sucking bugs, fruit flies and the leaf-miner. Among the former are aphids, scale insects and aleyrodids which frequently congregate on the twigs and young leaves causing much damage. The commonest aphid is *Toxoptera aurantii*, and among the scale insects usually encountered are *Coccus viridis*, *Aspidiotus aurantii* and species of *lepidosaphes*. The secretions of these insects provide a medium for the development of the "Sooty-mould" fungus upon the upper surface of the leaves on which the secretions fall, but this unsightly mould is not directly injurious. Parasitic fungi, such as *Cephalosporium*, exercise some degree of control upon certain scales, and aphids are preyed upon by Coccinelid beetles and Syrphid larvae. Aphids and some scale insects are cultivated and attended by ants which feed upon the secretions of these isects. As ants play an important part in distributing these pests for the purpose of founding new colonies it is necessary that their nests should be located and destroyed when in the vicinity of citrus trees. In small citrus groves and on individual trees

in private gardens where the infestation by the above plant-sucking bugs is not severe, the attached shoots may be removed and destroyed. On a large scale spraying must be resorted to and a soft-soap wash (1 lb. soap to 6 gallons water), or kerosene emulsions, can be recommended.

Fruit flies are occasional pests in some localities. They are difficult to control and reliance is usually placed upon the collection and destruction of fallen fruit and the use of poisoned baits to attract the adult flies before they oviposit; which is usually about four days after emergence. A good bait is made of 6 lb. sugar and 6 oz. arsenate of lead dissolved in 8 gallons of water. The bait is applied to the trunks of the trees requiring protection, or old tins and bottles containing the bait are hung from the branches of the trees.

The leaf-miner *Phyllocnistis citrella* is sometimes a very serious pest in the citrus nurseries. The larvae mine the tender leaves causing them to curl, and also tunnel in the younger twigs. In Japan it is customary to retard the development of leaves in nursery stock by increasing the phosphoric acid content and reducing that of nitrogen in the artificial fertiliser used. The application of a tobacco-soap wash is effective in destroying the young larvae but it is necessary to repeat the application periodically.

12. CONCLUSION

In conclusion, it should be remembered that citrus growing being at the present time in its infancy every care should be taken to ascertain the best type of tree, both stock and scion suitable to the locality, the requisite soil conditions and the many other factors involved in present day citrus culture.

Successful cultivation of these fruits is undoubtedly remunerative in other countries and it would appear possible to make it so in this colony provided that work in the investigation of the many problems of horticulture such as the influence of the stock on the scion and the relation if any, of such to bud variation; and later of transport and marketing, can be undertaken. The formation of small fruit stations in various centres for trials and experiments would appear a desirable proposition and the importance of these initial steps of development can hardly be over emphasised. Experiments of the various types of orange and grapefruit most suitable having been ascertained, cultivation should be restricted to the few and good, since advantage is gained where large quantities of fruit are produced from a small number of varieties. Uniformity of the type of orange and grapefruit produced is to be aimed at. A uniform type of fruit would be a great asset in establishing an industry in the future.

The possibility of Citrus production as a profitable minor product in Ceylon is feasible if the necessary care and attention is given to the subject at the outset. If sufficient interest is stimulated to lead to the opening up of small acreages of orange and grapefruit here and there in the Island on experimental lines, the object of this article will have been attained. The early stages of development are invariably the most difficult to negotiate and an outstanding difficulty at the moment is in obtaining locally sufficient and reliable sources of orange and grapefruit budwood.

The prospective grower is advised at this early stage to indent for budded plants from reputable nurserymen in either South Africa, Australia, the West Indies, or California and Florida, since there is little or no proved budwood of orange or grapefruit available in Ceylon and to limit his selection to the better known and tested varieties as those already mentioned in this article. Assistance in this respect is available through the offices of the Central Seed Store, Peradeniya, the season for imports of these fruit plants from South Africa being March, from Australia, July, and from the West Indies, September.

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CHEMICAL NOTES (9)

THE MANURIAL VALUE OF SPECIES OF OXALIS

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AT the request of the Chairman of the Soil Erosion Committee, analyses were made to determine the value of the species of *Oxalis* (*O. corniculata*, *O. latifolia*, *O. corymbosa*) as green manures. As the results of the analyses will be of interest to tea planters who have permitted *Oxalis* to grow on their estates as a means of checking soil erosion, it has been suggested that they should be published. In the table are shown the results of analysis of samples of each of the different species and the average results for the three species and for four species of leguminous cover crops (*Dolichos Hosei*, *Indigofera endecaphylla*, *Centrosema pubescens* and *Calopogonium mucunoides*). Two different samples of *O. latifolia* were examined, but only the mean of the two analyses is shown in the table. In the case of the *Oxalis* species analyses were made of the leaves and bulbs, but in the case of leguminous crops only the leafy green material was examined. The results of analyses will naturally vary with the nature of the sample, *e.g.*, its age, soil and climatic conditions under which it was grown, etc. The figures in the table cannot therefore be regarded as absolute, but they are representative of the manurial value of the species examined compared to that of leguminous cover crops.

TABLE

	Oxalis (leaves and bulbs)						*Leguminous crops (green material)*			
	O. Corniculata		O. Latifolia[x]		O. corymbosa		Average of all species			
	On dry matter at 100° C Per cent	On fresh material Per cent	On dry matter at 100° C Per cent	On fresh material Per cent	On dry matter at 100° C Per cent	On fresh material Per cent	On dry matter at 100° C Per cent	On fresh material Per cent	On dry matter at 100° C Per cent	On fresh material Per cent
Mosture	—	76·7	—	84 8	—	74·4	—	78 6	—	73·7
* Organic matter	89·2	20·8	90·3	13 7	89·5	22·9	89·7	19·1	89·6	23·7
+ Ash	10·8	2·5	9·7	1 5	10·5	2·7	10·3	2·3	10·4	2·6
* Containing Nitrogen ...	2·50	·58	2·25	·35	2·74	·70	2 50	·54	3·75	1·00
+ do Lime ...	1·71	·40	1·65	·25	1·62	·41	1·66	·36	2·63	·68
do Potash ...	2·18	·51	2·33	·36	3·87	·98	2·79	·62	1·60	·40
do Phosphoric acid ...	·64	·15	·62	·10	·70	·18	·65	·14	·55	·13

x Mean of two different samples.

An examination of the table will indicate that (1) of the species of *Oxalis* examined, the sample of *O. corymbosa* has the greatest manurial value, its organic matter, nitrogen, potash and phosphoric acid contents both on fresh material and on dry matter at 100°C being higher than those of either of the other species. The analytical differences between the individual species are not however very appreciable except in regard to the potash contents; (2) *O. latifolia* and *O. corniculata* have about the same percentages of fertilising materials on dry matter at 100°C, but as the proportion of bulb to leaf in the former is higher than in the latter and as the bulbs contain a higher moisture content than the leaves, the analytical figures on fresh material are lower for *O. latifolia*; (3) the average results for the three species of *Oxalis* examined indicate that they contain about 2·5 per cent nitrogen, 2·8 per cent potash, 1·7 per cent lime and ·7 per cent phosphoric acid as compared with 3·8 per cent nitrogen, 1·6 per cent potash, 2·6 per cent lime and ·6 per cent phosphoric acid, on the average, in the green material of leguminous cover crops, the data being reckoned in both cases on dry matter at 100°C. It will therefore be noted that while the *Oxalis* species have, as is to be expected, smaller nitrogen and lime contents than the green material of leguminous cover crops, they contain more potash and slightly more phosphoric acid than the latter. The average organic matter and total ash contents are the same for both varieties of plants. The average moisture content of the fresh material of the *Oxalis* species is slightly higher than that of the green material of the leguminous cover crops examined.

On the whole it will appear from the above analyses that the leaves and bulbs of *Oxalis* species have a higher value as green manure, compared to the leafy material of leguminous cover crops, than they may be generally supposed to have.

RUBBER YIELD RECORDS

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THERE appears to be considerable divergence of views and variation in the methods adopted in keeping rubber tree yield records on various estates.

It seems essential that some standard system should be adopted so that comparisons of records are facilitated as much as possible.

There are so many co-related factors to be taken into account when comparing yield records that it is admittedly impossible to supply a completely accurate visible result without wading through mazes of figures, but it would seem desirable that these co-relations should be aggregated, and then reduced to the nearest possible common denominator, so that the avearge estate superintendent and visiting agent should be able to tell at a glance, and within a measurable degree of accuracy, the order of merit of any tree of which records are being kept.

At present some estates show only the total yield of dry rubber per month or per annum. This method is clearly open to great error. For example, take three trees:

"A"	girthing	8 ft.	giving	100 lb.	per	annum
"B"	,,	4 ft.	,,	60 ,,	,,	,,
"C"	,,	3 ft.	,,	50 ,,	,,	,,

all in similar soil with the same number and method of tappings. Looking at the record one naturally selects "A" tree as the highest yielder; yet if one takes the girth of the respective trees into comparison it will be seen that "C" tree ranks first in order of merit with 33·2 lb. per foot of cut, "B" next with 30 lb. per foot of cut and "A" last with 25 lb. per foot of cut presuming them to be tapped on the half spiral.

Another system, certainly far more accurate than the above is that in which the average yield per tapping per tree is taken, and this appears to be the commonest system employed. One hestitates to query a method employed by eminent research workers; no doubt for excellent reasons, but it does appear that here again the girth of the tree is not as a rule taken into account, neither does the system allow of an accurate deduction being made if the tapping system be altered, say from $\frac{1}{2}$ to $\frac{1}{3}$ during the period the yields are taken. One must then interpolate one's own ideas as to what reduction or increase in yield has taken place for the given period since the alteration in the tapping method took place, providing the period be known, and this interpolation cannot possibly be even approximately accurate.

It would seem that the by no means perfect, but fairest system employable consists in the recording of the average yields per tapping per lineal inch of cut. This must of course be done

in grammes, or in decimals of ounces as the quantities naturally are rather small ones.

The writer employs a system of graphed charts put up in book form, one page being used per month. Each page shows at a glance the following information: 48 trees, their numbers, their ages, soil, girth, and state of canopy and number of tappings, their yield in grammes per tapping per lineal inch for the three previous years, their total yields for the same periods, and on graphed lines their average yield in grammes per lineal inch per tapping for the month, and their total yield in lb. and ounces for that month. A glance at the two graphed lines of yield shows immediately which tree ranks highest in order of merit, and this saves the time and trouble usually spent wading through columns of figures.

With this method it makes no real difference whether a tapping cut is suddenly changed to $\frac{1}{3}$ or $\frac{1}{4}$ from a $\frac{1}{2}$ during the tapping period, one has still the weight of dry rubber per inch of cut per tapping to go upon which will materially reduce the possibilities of serious error, and will even up to a considerable extent the interference of outside factors.

The obvious objection raised against this method is that any given mother tree or clone may possess as one of its inherent characteristics the ability to girth at a rapid rate, or *vice versa* the inability to do so, and that the tree which puts on girth quickly and inch for inch gives as high a yield as the poor girther is to be preferred to the latter on that score, and in that case this method of shewing the yield per lineal inch per tapping, would not show the true order of merit. This latter remark is true, and the system is admittedly not perfect, nevertheless it is a moot question as to whether the planting up of a large girther is preferable to the planting up of a small girther, the writer prefers within limits the latter, should there be any choice, and for this reason:

An average acre of land will only support under best planting practice a certain length of tapping cut per acre. The larger the tree the fewer the trees per acre, and *vice versa*. A fair average length of cut per acre would appear to be 260 feet. Let it be allowed that any given acre contains trees girthing 6 feet, then on the alternate half-spiral with a 3 feet cut per tree the number of trees per acre will work out at 86, or with trees girthing 4 feet at 130 per acre. With bud-grafting and high-yield-planting in its present state of development the higher stand per acre seems preferable and safer—one can afford to lose more trees. At 86 to the acre the loss of each tree will be felt to a greater extent, and on the pre-given figures the removal of one of these trees means the loss of 3 feet of tapping cut, whereas the removal of the smaller tree only involves the loss of 2 feet of cut at a time. This would seem to meet the only objection the writer has so far heard raised against this method of recording.

CONFERENCE OF EMPIRE METEOROLOGISTS, 1929

AGRICULTURAL SECTION

WEATHER AND CLIMATE IN THEIR RELATION TO INSECTS*

IT is not for me, an entomologist without any special knowledge of meteorology and climatology, to insist before the present Conference on the extremely complex inter-play of various meteorological elements which go to make a weather, or a climate. I am only going to attempt to show how these elements and their infinitely varying combinations influence the highly complicated organism of insects their life and activities, many of which are of supreme importance to man, since they concern his crops, health and even life.

The numerous problems of the influence of various meteorological factors on insects have formed the subject of many special studies, and the entomological literature is full of examples of such an influence. A full survey of the literature on these problems will be given elsewhere, and in the present paper I propose only to draw the attention of the members of the Conference to some outstanding points, in particular to those in the investigation of which a close co-operation between an entomologist and a meteorologist appears absolutely essential.

Let us consider briefly the influence of each of the main meteorological factors on insects.

Temperature.—The aggregate amount of work done on the influence of temperature on insects is very considerable and the main results may be summarised very briefly as follows:

The influence of temperature on insect activities is easily observable, since it results mainly in various more or less conspicuous movements. A general scheme for all activities of an insect as dependent on temperature is based on the conception of an optimum zone of temperature, within which all activities are most pronounced; above this zone lies that of a temporary heat stupor, still higher a zone of more prolonged inactivity or dormancy (æstivation) limited above by the zone of fatal temperatures; in the opposite direction we find the zones of cold stupor, of dormancy (hibernation) and of fatal low temperatures (Hunter and Pierce, 1912). All these zones and their limits naturally differ in cases of different insect species, even of different sexes and stages of development of the same species; moreover, each kind of activity—movements, feeding, pairing, egg-laying, etc., has its more or less definite optimum zone. The differences in the temperature range of activities between different species of insects may be very striking; thus, certain grasshoppers are fully active at midday in the deserts of Palestine when the surface temparature reaches over 140°F. (Buxton, 1924), while some aphids have been observed active and copulating at 19°F. (Bachmetjev).

* Paper read by B. P. Uvarov, Senior Assistant, Imperial Bureau of Entomology, before the Agricultural Section of the Conference of Empire Meteorologists 1929.

More detailed quantitative studies on temperature relations of insects have further shown that even the same individual may react towards a definite temperature in a different manner according to other external factors or internal conditions. Thus, woodboring larvæ of beetles freeze hard at—12·8°C, but only if the larva has been taken from its natural habitat in winter, while the same larva collected in summer freeze at —0·77°C. (Payne, 1927). This varying degree of cold hardiness in insects has been recently associated with the state of water in the insect body; namely, it has been found to depend on the balance between the free water which freezes easily and the water bound by colloids and hardly affected by low temperatures. This balance of water in its turn is connected with the moisture of the insect food, and with the general humidity of the habitat (Robinson, 1928). This one example already serves to demonstrate that the problem of the influence of temperature on insects has two different aspects, the meteorological and the physiological, the latter touching upon the still very obscure phenomena of the biochemistry and biophysics of colloidal substances.

The physiologial side of the problem makes it imperative that the influence of the temperature on the insect should be studied in such a way that not only the external temperature conditions and the corresponding reaction of the insect are taken into account, but due attention is also paid to the ability of the insect to absorb and to utilize the heat of the surrounding medium. This was realised long ago and a series of studies dealing with the effects of external temperatures on the internal body temperatures of insects are now available. These studies have demonstrated first of all, that insects, although always considered to be cold-blooded animals, possess some power to adjust the internal body temperature by movements, and are, thus, not absolutely dependent on the external conditions (Bachmetjev, Pirsch). Much more important is the observation that the degree of absorption of radiant energy varies very widely in different insects, apparently mainly in connection with their coloration. The coloration of insects, particularly of butterflies, has received a great deal of attention from experimental entomologists, but it is only lately that views have been expressed as to the possible importance of coloration in the thermal economy of insects. Direct experiments on the influence of particular colours on the absorption of radiant energy are still practically lacking (Buxton, 1924), but there is no doubt that this is one of the most promising fields of research, in which an entomologist should work together with a meteorologist and a physiologist, so as not to overlook any of the factors influencing both the radiation and the absorption and transformation of radiant energy within the insect body.

Most of the above considerations refer not only to the visible activities of insects, but also to the internal processes of their development, in which temperature plays an extremely important part. Experimental work under controlled conditions of temperature permitted the formulation of the connection between the external temperatures and the rate of development of insects, in mathematical terms, but it must be admitted that we are still far from exact knowledge and understanding of the phenomena involved (Bodenheimer, 1926). The first idea of this connection was very simple; it was assumed that the development of an insect begins and stops at a definite temperature which was called the zero of development. It was further assumed that every degree of temperature above the zero acting during a day corresponds to a definite and equal advance in the development of an insect. With these assumptions it was easy to calculate the number of "day-degrees" necessary for the accomplishment of a certain stage of development, once the sum of effective temperatures for this stage had been determined experimentally. However, later investigations demonstrated that the conception of a constant sum of effective temperatures

necessary to complete a stage is a fallacy and that the actual sum varies within very broad limits, making the practical use of the principle out of the question. For example the beetle *Sitodrepa panicea* requires 1,820 day-degrees at 20°C. and 3,638 at 17°C. The reason for this lies in the fact that the action of one degree of temperature during a definite period of time is not the same at different temperatures; in other words the value of day-degrees is not constant but may be 2-3 times as high at certain temperatures as at others. Special curves and formulæ have been constructed to express the relationship between temperatures and development and some of them (*e.g.*, Blunck's formula) proved to be fairly useful for practical calculations of the period of time necessary for the accomplishment of a definite state of development under certain conditions. It would carry us too far to discuss here all the details of this relationship, and I restrict myself to a broad indication of its main features. First of all, it must be realised that under the term development many very different internal processes are included, mainly the growth, the formation of genital products in the insect body and the formation and growth of the embryo in the eggs. As may be expected, all these processes are accelerated at a higher temperature, within the optimum limits, of course. As a result of this acceleration, each stage, and the whole life cycle of a given insect may be substantially different in length, according to the temperature, and this is reflected in the fact that certain insects develop only one complete generation a year in cold climates and several annual generations in warmer ones; the practical importance of this difference is obvious, since in the latter case there will be several periods of injurious activities, if the insect in question feeds on cultivated plants. The formulæ referred to above permit of the calculation of the number of annual generations of a given insect possible in any given locality, if the temperature conditions of the latter are known, and this is being done with a certain degree of exactitude (Bodenheimer, 1926). There are several reasons why absolutely exact results cannot be attained.

To begin with, the mean temperatures for more or less long periods, not shorter than a day, are usually made the basis of calculations, but such means do not correspond to the exact quantity of heat energy received by the insect during the period. Indeed, the latest work on these lines with the codling moth led the investigator (Shelford, 1927), to the conclusion that temperatures cannot be summed up correctly for biological purposes, unless readings are taken in intervals of one or two hours, throughout the whole period of the development of the stage in question. It is obvious that this method is extremely cumbersome. A still further source of inexactitude of the theoretical conclusions as compared with the actual course of events in nature depends on the fact that all our formulæ and curves are based on experiments at constant temperatures, while there is no constancy of temperature in nature, and mean temperatures for a given period have to be used in the calculations. Recent experiments have proved that the fluctuations in temperature exert a considerable accelerating influence on the rate of development of insects (Cook, 1927). Thus, daily fluctuations in the temperature are not without their direct importance. Similarly, the annual range of temperatures in temperate climates has its significance, quite apart from the arrest of development during the cold months; it has been found for instance, that winter cold has an accelerating action on the rate of development of grasshopper eggs, which hibernate in soil and hatch in spring. The eggs kept throughout the winter at a constant temperature of 23°C. developed in 45 days, while the eggs kept in the open air for 39 days and then subjected to a constant temperature of 23°C. required only 40 days for their development (Bodine, 1925). The reasons

for this somewhat surprising stimulating effect of fluctuations in temperature, and in particular of low temperatures, are still obscure, but this is a problem for a physiologist to solve and we may leave it alone.

An excellent illustration of the complexity of temperature relations of insects is presented by the differential effect of the same external temperature on an insect and its parasite. The rate of development of the wheat aphid *Toxoptera graminum* is faster than that of its parasite *Lysiphlebus tritici;* the threshold of development for the host is 32°F., while for the parasite it is 36°. At a mean temperature of 68° a parasite would develop in 264 hours, and a host in 240 hours; while the parasite was developing, a host female would have produced 26·4 young aphids. The parasite would ordinarily sting 22 aphids during the two days following its emergence, when the total progeny of one host female would be 31·2 individuals, thus being 9 individuals ahead of the parasite, which therefore, can never exterminate the host. It is easy to see how relatively small differences in the activity range of the host and the parasite and their rate of development as affected by temperature, may become a deciding factor in the abundance of both insects (Headlee, 1917; Shelford, 1926).

A somewhat parallel case is that of insects and certain micro-organisms associated with them, which are of exceptional interest, being the causative agents of the most dangerous human diseases. For example, temperature exerts a direct effect on the malaria parasite within the mosquito; low temperatures, not in themselves injurious to the mosquito, inhibit the development of the parasite; on the basis of this, it is possible to define the areas and seasons which are dangerous from the point of view of malarial infection through mosquitos (Gill, 1921). With regard to the plague bacilli which are carried by fleas it has been found that a temperature of 85°F. (29·44°C.) caused a more rapid disappearance of the bacilli from the stomach of fleas than that of 70°F., while at the low mean temperature of 50°F. infected rats often died before plague bacilli appeared in their blood, so that their fleas had no chance to become infected (Rogers, 1928). Further highly interesting observations refer to the effect of temperature on certain symbiotic micro-organisms of locusts, in which they live at normal mean temperatures without any apparent harm to the host, but at low temperatures the symbionts tend to increase to such an extent that the development of genital products of the locust is inhibited and a fatal disease may follow. In other cases, normally saprophytic fungi proved capable of becoming dangerous parasites of caterpillars at sufficiently high, though not in themselves injurious temperatures.

The effects of the temperature factor on the geographical, topographical and seasonal distribution of insects will be discussed later, as humidity has also to be taken into consideration, and we must first review the available information on the influence of this factor by itself.

Humidity and Precipitation.—Although exact quantitative observations on the effects of the relative humidity of air on insect activities are not yet sufficiently numerous, the data accumulated enable one to conclude that the scheme of the relations of insects to humidity is essentially the same as that with regard to temperature. In other words, it may be assumed that a zone of optimum humidity, as well as upper and lower fatal limits exist for each species and each stage of its development. There is no doubt, however, that variations in this respect are still greater than in the case of temperature, since the physiological influence of the humidity of air on the insect must be less direct than that of its temperature. Indeed, insects obtain most of the water necessary for their internal physiological processes with their food and not from the air, so that the main influence of the water vapour contained in the air is through evaporation, which we will

discuss later. There are direct indications that the water obtained with food may make an insect practically independent of the atmospheric humidity; thus, the aphid *Toxoptera graminum* feeding on sap of grasses takes six days from birth to maturity under a constant temperature of 80°F. and relative humidities ranging from 37 per cent. to 100 per cent. (Headlee, 1914). Moreover, even eggs of some insects *e.g.*, cotton seed bug *Oxycarenus hyalinipennis*) (Kirkpatrick, 1923), do not show any difference either in the percentage of hatching or in the length of development in relative humidities ranging from one to 100 per cent.; in ths case, however, a possibility that the evaporation was prevented by the shells of the eggs is not excluded. Other experimental data on the subject show somewhat varying results and a definite rule as to the influence of relative humidity of the air on the rate of development of insects cannot, at least at present, be laid down. This conclusion may be explained by the fact that the concentration of body fluids differs widely in different insects and in the same insect during its development, so that similar conditions of atmospheric humidity may have very different physiological effects, the same relative humidity being fatal in one case, and representing optimum conditions, or being without any importance, in another.

One important effect of high humidity of air is that at certain temperatures it is highly favourable to the development of various fungus diseases of insects and thus becomes an indirect controlling factor.

Data with regard to the influence of *precipitation* on insects, cannot of course be very exact, since the effect of the precipitation are bound to be mainly indirect, acting through the corresponding changes in the evaporation and therefore, being closely connected with temperature, wind, atmospheric pressure, etc. Another effect of precipitation is the change in the moisture content of the soil which is highly important, since a great percentage of insects pass one stage or another in the soil. These problems involving more than one factor will be discussed later.

The direct effects of rain on insects are mainly mechanical and consist in the destruction of more tender stages, or in the drowning, particularly by rainstorms; there are cases on record which show the great controlling value of this factor. A very common example of the direct influence of rainfall is its effect on the emergence of insects from quiescent stages, *i.e.*, from eggs or pupæ, or from hibernation. The effects are partly due to the mechnical action of water on the outer covering of pupæ (cocoons) or egg-shells, which can be burst only when softened, while in some cases the effects must be connected with the absorption of water necessary for completing the development of the stage or the resumption of the physiological activities.

Indirect controlling influence of rainfall through the vegetation is very important. Apart from those cases when drought conditions cause a mass destruction of phytophagous insects through lack of their food-plants, the connection between rainfall and the abundance of an insect is often very obvious and undoubtedly indirect, *i.e.*, through the vegetation. Outbreaks of certain bark-beetles for example, are definitely connected with the periods of rainfall deficiency. On the other hand the propagation of certain insects, like aphids, is favoured by increased rainfall, provided the rains are not sufficiently heavy to cause their mechanical destruction.

Perhaps most important of all is the distribution of rainfall throughout the year. Usually this factor acts in conjunction with the seasonal temperature régime, but there are cases of the influence of rain alone. Thus the most important factor in the balance of the coffee-borer (*Stephanoderes hampei*, Ferr.) in Java and Sumatra is the distribution of rainfall throughout

the year. In certain areas it rains at all seasons and the flowering of coffee-plants and ripening of berries is spread over the whole year, so that the insects find food continually and their generations follow each other without interruption. In other districts the east monsoon brings with it a dry period of several months' duration, and the west monsoon is accompanied by continuous rains, which prevent the flowering of coffee. Thus a period when no food is available for the pest is interpolated each year and during this period the beetles die out, with the exception of few survivals (Friedrichs, 1925). Another example of indirect influence of rainfall is presented by the tsetse fly (*Glossina morsitans*) which is closely connected with shady forests; the leaf fall in African forests is dependent mainly on the rains and thus the latter become an important factor in the seasonal movements of the fly (Swynnerton, 1921).

Very little data exist with regard to other forms of precipitation besides rain. Snow has an important function as a protection from winter frosts of insects hibernating in the soil or on its surface. Hail has been recorded to cause great mechanical destruction of various insects, but the controlling value of this factor is, of course, practically negligible.

Wind.—There can be no direct influence of any movements of air on the development of insects, but the activities, particularly of those insects which use their wings for flight, are bound to be affected by winds. In most cases the influence is negative, at least as regards winds of higher velocities, but it must be confessed that quantitative observations in this direction are practically lacking. The relations of flying insects to wind are still insufficiently studied, though certain observations on the flight of nocturnal insects tend to show that many of them are inclined to fly against the wind and not with it. However, no general rule can be laid down (Lutz, 1927). A number of exact observations have been made on the wind dispersal of insects, demonstrating clearly the importance of winds in this respect. It was found that normal dispersion of a number of insects, like the Hessian fly, Gipsy moth, etc., depends on prevailing winds perhaps more than on any other agency (Webster, 1902; Collins, 1915). There are some cases on record which illustrate the importance of winds in carrying insects over unexpectedly long distances, as for example the appearance of winged spruce aphids on the snow at Spitzbergen, where they could have been brought only by wind from the Kola Peninsula—a distance of over 800 miles in a straight line (Elton, 1925). Tropical cyclones must be particularly powerful agents in the dispersion of insects from island to island, but so far the actual data are neither numerous nor sufficiently exact.

The importance of the upper air currents in the dispersal of insects has been stressed recently (Felt, 1928), but the evidence in favour of this view is very meagre and exact observations of the insect fauna of the upper layers of atmosphere are badly needed.

Indirect action of winds as a factor of evaporation must also be of great importance.

Atmosphoric Pressure.—Direct effects of atmospheric pressure on insects are substantially different from those on higher animals, probably owing to the fundamental difference in the respiratory and circulatory organs. Experiments on the influence of a vacuum on insects gave very surprising results, since bumble-bees subjected to a super-vacuum of $\frac{1}{10000}$mm. for 90 seconds and then suddenly returned to the normal pressure remained unharmed and active (Lutz, 1929). This shows that ordinary changes in pressure occurring in nature can be hardly of any direct importance in insect life, at least, not as controlling factors.

At the same time, there is some evidence that the general activities of many insects increase with barometric depressions, and there are also definite and sufficiently exact observations and experiments on the influence of depressions on the length of the pupal period of butterflies and moths, as well as on their emergence from the pupæ. It has been found that a uniform normal pressure maintained throughout the pupal period prolongs the latter, while a uniform reduced pressure shortens it considerably (*e.g.*, in *Pieris rapae* the stage lasted only 9 days at pressure 710-728 mm. instead of the normal 15 days). The emergence of adults in the great majority of cases does not take place except on the fall of barometric pressure, a diminution of pressure by one millimeter being sufficient to induce the eclosion of an adult which is ready for it. The action of pressure on eclosion must be purely mechanical: the adult insect within the pupal skin is unable to burst it until a drop in atmospheric pressure creates a difference between the latter and the pressure of the body fluids (Pictet, 1917).

It must be admitted that observations on the direct influence of pressure on insect activities and development are still very fragmentary.

Indirect influence of pressure is through winds and evaporation and does not need a separate discussion.

Atmospheric Electricity.—No exact data exist in this respect, but it is generally known that many insects, especially the nocturnal ones, are more active before a thunderstorm.

Light.—Observations have been made which tend to show that the production of sexual forms in aphids depends on the direct action of light, since under experimental conditions sexual forms were produced earlier and more abundantly in the case of shorter exposures to artificial light, while long exposure had an inhibiting influence (Marcovitch, 1924). These observations were contradicted by other observers and final conclusions must be deferred. Further studies of light as a factor of development are highly desirable, since light has been greatly neglected in the past.

The influence of light on activities of insects has not been sufficiently studied, though the existence of strictly diurnal and nocturnal insects already shows that the reactions of different species towards light are very dissimilar. So far, however, exact observations on the quantity and quality of light necessary for various activities are very scarce and of uncertain value.

Combination of Factors.—The most important complex factor exerting very great influence both on the activities and on the development of insects is the evaporating power of air, which depends on the temperature, humidity, air movements and atmospheric pressure. Physiological reasons for the importance of this factor are obvious, since all biological processes take place in a liquid or semi-liquid medium, and the deficiency or the excess of water in the organism is bound to affect the rate, or even the direction of the process. Indeed, it is almost certain that evaporation causes an insect to react very differently towards the same temperature if the relative humidity varies. For example, the cotton seed bug dies after 150 hours' exposure to 25°C. at 60 per cent. humidity, but at 80 per cent. humidity the exposure must be twice as long to be fatal (Kirkpatrick, 1923); it is very probable that death from high temperature is due to excessive loss of water, which is greater at lower humidities. On the other hand, very high humidities may be injurious through preventing evaporation, which tends to lower the body temperature and thus to moderate the influence of heat. Another case of combined effect of humidity and temperature is presented by the resistance of insects to very low temperatures. This resistance depends greatly on the water content of the insect; low evaporation rate makes hibernating insects less resistant to freezing through increasing their

water content (Payne, 1927). As regards the development of insects, several investigators found that its rate is increased at lower humidities, though the temperature conditions remain the same. This must also be connected with the rate of evaporation.

In view of these and similar facts, it is only natural that many entomologists consider observations on the evaporating power of air highly important for their purposes. They are probably right, at least in considering that these observations present the simplest method of evaluation of the combined effect of practically all the main meteorological factors. However, it must not be forgotten that this method makes the appreciation of the exact value of each separate factor more difficult; the exact quantitative analysis of factors should be the aim of ecological investigations.

Very little data exist with regard to combined action of other meteorological factors, except those involved in evaporation. Light in combination with temperature and perhaps with humidity may be a controlling factor in certain activities of insects. For example, the codling moth lays its eggs only in the dark, and only at a temperature not below 62°F.; if the temperature falls below that figure before it is sufficiently dark, no eggs are laid. Thus the propagation of the species depends on the favourable combination of the two factors—absence of light and temperature (Iselby and Ackerman, 1923). Diurnal insects, on the other hand, are more sensitive to light at higher temperatures and an optimum combination of the two factors may be of the greatest importance for the species.

Climate and Weather.—With this preliminary acquaintance with the influence of various meteorological factors on insects, we can now turn our attention to the main general effects on them of climate and weather. These effects may be conveniently grouped under two headings—distribution of insects in space (geographical and ecological) and their distribution in time (seasonal and periodic cycles).

Geographical and Ecological Distribution.—It is not proposed to discuss here the various means of dispersal of insects; it is sufficient to say that each species has a natural tendency to spread as widely as possible and every possible agency is utilised for this purpose, so that there is a theoretical possibility for each species to populate the whole surface of the earth. This possibility is, however, very seldom realised, and the number of truly cosmopolitan insects is very small; practically all of them, moreover, live in close association with man, *i.e.*, under conditions which make them independent of the differences in the natural conditions of various countries. The great majority of the remaining insects are restricted to more or less definite geographical areas, and the factors limiting their distribution are almost entirely climatic since the geological factors of distribution also depend mainly on changes of climates throughout the ages.

The area of distribution of an insect species is obviously that in which the combination of all climatic and biotic factors permits its survival. It is usually considered that every organism is adapted perfectly to the conditions of its existence, but this seems to be a principle based on theoretical considerations and not in accordance with facts. Indeed, recent studies on the climatic factors controlling insects appear to emphasize that the percentage of survival of progeny is normally very small, the bulk succumbing to the numberless adverse influences of the normal environment. In other words, insect species survive not because of their wonderful adaptation to environment, but in spite of the insufficient adaptation and owing to their high reproductive abilities. Indeed, these abilities are such, that given really optimum conditions of existence, almost any insect species would become exceedingly abundant within a short time, as is proved by periodic mass outbreaks of injurious insects, dependent mainly on the optimum combination of all factors.

The climatic factors limiting the area of distribution of an insect are mainly temperature and humidity, or the evaporating power of air dependent primarily on them. Thus, the northern limit of the brown tail moth in North America coincides with the minimum isotherm-35°C., while the asparagus beetle (*Crioceris asparagi*) cannot extend its range beyond the minimum isotherm-10°C. (Sanderson, 1908). The cabbage butterfly (*Pieris brassicae*) reaches its southern limit of distribution in Palestine, since it can successfully live there only in winter months, while the summer heat kills nearly 100 per cent. of eggs and young larvæ (Bodenheimer, 1928).

Humidity in itself is undoubtedly a very important factor of distribution, but the data on its limiting rôle are few and inexact. Much better studied is the combined effect of temperature and humidity, or temperature and precipitation, and in this direction great advances have been made recently, owing to the extensive use of Ball-Taylor climographs and hythergraphs, which permit the correlation of the distribution of an insect with the two main climatic factors (Cook, 1924; Shelford, 1926; Tehon, 1928). Their application demonstrated, in particular, that it is often not the absolute averages of temperature and humidity, or their maxima and minima that limit the distribution, but the seasonal temperature and rainfall régime. This is easy to understand since an insect has its own seasonal cycle and its different stages of development have different requirements.

The practical use of climographs in entomology is especially important in the case of insect pests introduced, as happens very often, from one country to another. Climographs of the original home of the insect permit us to understand the conditions of its existence there, and a study of climographs of the new country enables us to judge what are the chances of its acclimatisation in particular areas there.

The method of climographs has, however, its limitations. One reason for its inexactitude lies in the fact that it is based on mean monthly temperatures and humidities, while we know the great importance of fluctuations in both for insects. Another and much greater source of error lies in the fact that climographs have to be based on the data provided by meteorological stations. Meteorologists, for obvious and excellent reasons of their own, adopted certain standardised methods of taking observations, and this standardisation makes many of their data of very little value to us. Temperature readings taken in Stevenson screens and then reduced to the sea-level value, have obviously a very distant relation to the temperatures to which insects are normally exposed, while the hours of taking observations are fixed, naturally, without any regard to various activities of insects. The same remarks apply to observations on relative humidity. The fact is that the climate of a locality as studied by meteorologists has probably much less significance for insects than the micro-climates of the widely varying habitats of insects. Detailed observations on temperature and humidity in a forest, for instance, show that the means and the range of daily, monthly and annual fluctuations differ widely at different heights from the ground (Weese, 1924). This means that standardised observations taken near, or even in the forest, would not express the conditions of existence of most of the forest insects.

Similarly, the exposure of slope, the relative density of vegetation, slight depressions of surface, etc., all affect the micro-climate and make standard observations inapplicable in each particular case. The problem becomes even more complicated in the case of insects living inside plants, or parasitic on other animals, or otherwise isolated from the direct influence of meteorological factors, though still dependent on them indirectly. It has been found, for example, that the temperature within an open boll of the cotton plant (in which several important pests live) is lower than the shade temperature during the day, while at night the minimum within the

boll is above that of the air (Kirkpatrick, 1923). In the case of desert insects, it has been found that a great number of them pass the day burrowed into soil, or in caves, etc., coming out only at night, with the result that their conditions of existence have a very remote relation to the desert climate as represented by oridnary mteorological data (Williams).

All these considerations show that exact knowledge of meteorological factors limiting the distribution of an insect can be only obtained through detailed and prolonged studies of the micro-climate of its habitat, or rather habitats, since most insects change their habitat during development, the larvæ, *e.g.*, feeding openly on foliage, the pupa being buried in the soil, the adult flying about, and the eggs being concealed under the bark of a tree, etc. The problem, thus becomes bewildering in its complexity, and its successful study depends only on the realisation of difficulties and their solution by the combined efforts of entomologists and meteorologists.

While stressing the importance of micro-climatic observations, I am far from implying that the standard meteorological data are quite useless for entomological purposes. On the contrary, as I have already said, some very valuable practical results have been obtained by studies of climographs in connection with the distribution of insects. This is only natural, since in these studies climographs serve for comparison of two or more climates, and the relation of climatic factors as observed under standard conditions to the micro-climates of definite habitats in different countries must be essentially the same. I would even venture to suggest that it might be possible after careful studies to find out the relation for each particular case, *e.g.*, to find an empirical formula, which would permit the calculation of the temperature within a cotton boll from the standard readings of temperature.

On the other hand, the importance of meteorological data for various local agricultural and biological problems is so very great that it would be legitimate on the part of representatives of those sciences to ask meteorologists to consider some alterations, or amplifications of the standard methods of taking observations in order to make them more readily utilised.

Cycles and Periodicity.—Seasonal periodicity in insect life is commonly known, and its direct dependence on annual fluctuations of temperature in colder regions appears obvious. Recent studies, however, throw some doubt on the popular idea that it is only the winter cold which is directly responsible for the phenomenon of hibernation, *i.e.*, the state of more or less complete inactivity, in which most insects pass the winter. Indeed, it was found that in cases of insects normally hibernating, *e.g.*, in the egg stage, the eggs cannot be brought to development, even if kept at sufficiently high temperature. Facts of this kind point to the existence in insects of our latitudes of an inherited, fixed annual cycle of development, which is not easily altered by external conditions. There is little doubt, however, that this fixed cycle is due not to some mysterious agency, but has developed in the course of thousands of generations as a direct response to the environment.

Hibernation of insects presents special interest for our problem, since in this state of inactivity they are more than ever subject to unfavourable meteorological influences, and the winter mortality of hibernating stages is usually very high. It is worth mentioning that this mortality is much less due to the direct action of cold than may be supposed. Indeed, all known facts support the idea that long, severe winters, with frost and snow, do less harm to hibernating insects than milder winters with intermittent frosts and rains. This is due to the fact that most insects can survive even repeated freezing without any harm, provided their water balance is properly adjusted, while mild moist winters tend to disturb the balance unfavourably with disastrous results; besides, various fungous and bacterial diseases of insects develop more readily in mild weather.

The great majority of insects of temperate climates have only one complete generation a year; some take several years to develop, while there are many which have a shorter period of development and are able to produce several generations in one year. In the case of the last-named group, the number of generations per annum naturally differs according to the latitude, and this affects the relative economic importance of an injurious insect in different countries. Since the rate of development depends, as we know mainly on the temperature, it is possible, by means of certain formulæ mentioned above, to calculate the possible number of annual generations of a pest in any given country. Some more or less successful attempts in this direction have been made.

While we have some knowledge of the annual cycle of insects in temperate climates and of its causes, the same cannot be said with regard to sub-tropical and tropical areas. Theoretically, it would appear that the development of insects there should go on without interruption all the year round, and as many generations be produced as are consistent with the length of the period required for one full generation. This is, however, not so, and many tropical insects seem to have definitely only one annual generation. However, I must stress that exceedingly little is known on this subject. The interesting fact about insects of hot climates is that many of them have their resting stage also, corresponding to the hibernating stage of insects of higher latitudes, but not connected with temperature. The factor regulating the annual cycle of insects in hot climates appears to be the humidity of air and of the soil, and the resting stage normally corresponds to the dry period. It has to be admitted, however, that the phenomenon of aestivation, as it is called, is still very little studied. Hibernation and aestivation present major correlations of the annual life cycle of insects with the seasonal weather, and side by side with them there is a number of minor adjustments which are none the less important for the insects themselves, and for man. There are various phenomena of phenological order, *i.e.*, the appearance of different stages in development and their transformation, which should be studied in connection not only with the weather conditions, but also with the corresponding seasonal phenomena in the plant world. The importance of exact correlation of the appearance and development of an insect and of its food plant is often very great. Thus, the apple-blossom weevil (*Anthonomus pomorum*) lays its eggs in flower-buds of apple, and the larva must not only hatch, but fasten the unopened petals from the inside by a web, before the flowers begin to open; if the spring is cool and the buds mature and open slowly, the progeny of the weevil is safe, but in hot weather it happens often that the flowers open before the newly-hatched larvæ have time to prevent them from doing so and the larvæ fall out and die. In this way the life of insects and the degree of their economic importance depend on very small fluctuations of meteorological factors, which may affect the plant and the insect in a slightly different way, and thus turn the balance between them in favour of one and to the detriment of the other.

Extensive studies in the phenology of insects and plants led the American entomologist Hopkins to formulate his bioclimatic law, the main point of which is that "other conditions being equal, the variation in the time of occurrence of a given periodical event in life activity in temperate North America is at the general rate of 4 days to each one degree of latitude, 5 degrees of longtitude, and 400 feet of altitude, later northward, eastward and upward in spring and early summer, and the reverse in late summer and autumn. This law is purely empirical, and its theoretical significance is limited, while the practical application is possible only in normal seasons and under equable ecological conditions, which two requirements are seldom satisfied. Further, the law holds fairly good for North America only and

attempts made by its author to extend it to other continents remained theoretical, without a practical test, at least as regards insect phenology.

Much more promising are the attempts to base the forecasting of seasonal phenomena in the life of insects on the series of controlled experiments which supply the necessary data on the standard average period for the completion of a certain stage of development under controlled conditions of temperature and humidity. If meteorological observations are then carried out throughout the period of development of the stage in nature, and the results are summed up, it becomes possible to predict the completion of the stage and the appearance of the next one some time before it happens in nature. Such a forecast may be of great practical importance, for example in the case of the codling moth, where it is necessary to spray as near as possible to the time of hatching of the larvæ from the eggs (Shelford, 1927). The practical application of this method is, however, greatly limited, since it requires, first, a very extensive series of experiments under controlled conditions, with the use of complicated and expensive apparatus, and secondly, the taking of readings of temperature and humidity at 1-2 hourly intervals throughout a considerable period.

Apart from the seasonal rhythm in the appearance and activities of insects, there is a more or less strongly marked periodic fluctuation of a species from year to year. Only relatively few insect pests are equally numerous and injurious every year, while most of them are practically negligible, except in certain years, when mass outbreaks occur. It would be out of place to discuss here all the causes for these periodic fluctuations, but I would like to point out that recent researches in this direction tend to throw some doubt on the commonly accepted idea that the chief controlling factor is the parasites, since a number of cases have become known in which the factors normally keeping an insect species down are almost entirely of meteorological order. This has been admitted for the cotton boll weevil in America (Hunter and Pierce, 1912), for the corn-borer in Europe (Thompson and Parker, 1928), for the almond sawfly in Palestine (Bodenheimer, 1928), for the cotton seed bug in Egypt (Kirkpatrick, 1923), for plague fleas in India (Hirst, Rogers), for vine-moths in Europe (Stellwaag, 1925), and for some other notorious pests. The underlying principle of the fluctuations in number of insects resulting from climatic factors is that the optimum range of each factor is often relatively narrow, and a realisation of optimum conditions for the complete set of factors leading to an outbreak can occur only at irregular intervals, sometimes only after a series of favourable years. Dependence of the fluctuations on meteorological factors has often been suggested on the basis of the general impression that a certain pest becomes abundant, *e.g.*, in very dry years, but it is only recently that the study of the relations of insect outbreaks to climatic factors obtained a firmer footing through the use of climographs. It is now more and more customary, when studying an injurious insect, to construct climographs for a series of years, or for several localities, and, by comparing and correlating them with the relative abundance of the insect, to obtain an idea as to the climatic conditions favourable to its outbreaks. Since three quantities, viz., temperature, humidity and the abundance of pest, enter into the scheme, it has lately been suggested that three-dimensional graphs should be used to express their inter-relations. Such graphs have not yet been subjected to sufficient tests, and their practical utility cannot be considered as proved, although theoretically they present the only correct solution of the problem.

What has already been said with regard to the shortcomings of climographs in the studies of distribution of insects, holds good in the application of climographs in the studies of the fluctuations in the abundance of an insect. It must be realised that only approximately conclusions can be made

with regard to the value of one, or the other, of the climatic factors involved in the periodic fluctuations, as long as the climographs are based on the standard meteorological data, and not on the micro-climatic observations in the actual habitat of the insect under investigation. Another way out is a study of the correlation between standard meteorological data and the micro-climatic conditions of the habitat, so that the standard data can be converted to represent the micro-climate, but this has not yet been attempted.

If the relative abundance of an insect and its fluctuations have been studied on the basis of a large number of data, the deductions obtained may be used for forecasting the possibility of an outbreak of the insect. For example, outbreaks of the American pale western cutworm (*Porosagrotis orthogonia* Morr.) have been found to depend on the total amount of rainfall in May, June and July of the preceding year; the critical amount of precipitation varies with the temperature and produces a definite critical soil moisture. If the moisture exceeds the critical amount, the number of cutworms decreases in the following year; if the moisture be less than the critical amount, the number of cutworms increases. The effect is cumulative and severe outbreaks may follow a series of dry years (Cook, 1927). In this case the possibility of forecasting an outbreak is clear, and there is little doubt that the climograph method will prove its usefulness in this respect in many other cases, if properly applied and based on sufficient data. At the same time, it must never be forgotten that the factors controlling the abundance of an insect may be, and often are, other than temperature and humidity, so that a blind application of climographs to every case would be unreasonable.

My present survey of the problem of the relations of insects to weather and climate has been much too brief to permit the discussion of all its aspects. I hope, however, that I have at least succeeded in one of my aims—namely to illustrate the importance to entomologists of meteorological and climatological studies. There is a vast number of entomological problems which cannot be solved without the friendly help of meteorologists, and it is to be hoped that a close co-operation between these two sciences will rapidly develop in the immediate future.

THE BALANCE OF NATURE*

THIS old-fashioned phrase, "the balance of nature," sums up many interesting facts which show that animate nature is well-adjusted to keep agoing, and that smoothly. Living creatures have been sojourning together on the earth and in the waters under the earth for so many hundreds of millions of years that they have become adjusted into a *system*, which has staying power, and is not always stumbling to pieces. Their numbers and their claims have attained to some degree of harmony; and though this is often disturbed locally or temporarily, there is an automatic tendency to get back to a viable balance.

On the Scandinavian tablelands there are large numbers of little rodents called Lemmings—like small editions of Guinea pigs; and every four years or so (in the period since precise observations began) there is an over-population crisis. The lemmings, having outrun the means of subsistence, having, in fact, devoured all the vegetation, unite in companies and go on a march, from which there is no return. Large numbers are found drowned on the shores of the Baltic and the North Sea, and most of the trekkers come to grief in other ways. Yet after a couple of years things are once more as they were. The balance has been restored. Lemmings are still flourishing, but for some other types in the past such crises have proved too serious, and species have been exterminated. Yet even more striking is the tendency that things have to right themselves.

A Wave of Life.—In his *Naturalist in La Plata*, W. H. Hudson tells of the summer 1872-1873, that it was rich in sunshine and showers, blossoms and wild bees. But the fine weather was also very favourable for mice, which devoured the bees in their nests, and became so numerous that one could scarcely walk anywhere without treading on them. Cats became wild hunters; dogs ate almost nothing but mice; foxes, weasels and opossums fared sumptuously; tyrant-birds, Guira cuckoos, and even fowls became mouse-eaters. Countless numbers of storks and short-eared owls came to assist at the bountiful feast. But the winter was one of continued drought; the herbage was consumed or turned to dust, and, with the disappearance of their food and cover, the mice ceased to be. The army of enemies, now retreating with discretion, cleared off the residue of mice so thoroughly that "in the spring of 1873 it was hard to find a survivor." The wave of life was lost in the sand, and soon things were as though nothing had happened.

Plants and Animals.—What we wish to do in this article is to analyse and illustrate the ecological idea of the Balance of Nature. We naturally begin with the most fundamental relation, that between green plants and animals. Those who have tried will admit the difficulty of adjusting the balance of plants and animals in a self-contained aquarium which is not artificially aerated. At one time the plant gets the upper hand and may so crowd the water that the animals have not room to move about. At another time, the animals get the upper hand, and by devouring all the plants leave the water so poor in oxygen and so abundant in carbon dioxide that they suffocate. In other cases the animals are poisoned by their own nitrogenous waste-products, which are normally absorbed and utilised by the green plants. Now the point is that these aquarium disasters are unusual in natural conditions.

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* By J. Arthur Thomson, M.A., LL.D.; in *The Journal of the Ministry of Agriculture*, Vol. XXXVI, No. 9, December, 1929.

The most fundamentally important vital process in the world is the photosynthesis effected by green plants. The plants utilise the energy of the red-orange-yellow rays of the sunlight to build up carbon dioxide and water into sugars and other carbon-compounds at the same time liberating oxygen as an all-important by-product. The carbon-compounds made in the green leaves form the food of the plants themselves, and of all the animals that feed on plants. Even when the animal is a thoroughgoing carnivore, a few links in the nutritive chain bring us back to green plants. All flesh is eventually grass and all fish is eventually diatom. The green plant whether grass or diatom, finds the raw materials of its food in carbon dioxide, water, and dissolved salts; and the synthetized nutritive compounds —carbohydrates, fats, and proteins—are abundant enough to sustain the animal world as well as the plants themselves. Locally and temporarily, as in plagues of voles or of locusts, the animals may devour all the available plants; but it is plain that this is a rare, not a normal, occurrence. On the whole, the nutritive balance is preserved.

Not less important, though less frequently realised, is the fact that green plants have made the oxygen of the air, on which animal life depends. The original atmosphere of the earth was rich in carbon dioxide and water vapour; it had also some nitrogen, but very little oxygen—the production of which was and continues to be to the credit of green plants.

The Living and the Dead.—Surprise has often been expressed at the fact that we do not usually see many dead animals lying about. After storms the flat beach is sometimes strewn with sponges, zoophytes, jellyfishes, starfishes, sea-urchins, and molluscs which are thrown up in profusion by some peculiar combination of wind and wave, but on land it is very rarely that we see any analogue of this jetsam. We have known of two hundred small birds being gathered in one farmyard after a night of very severe frost, but such an occurrence is so rare in North Temperate countries that we remember it all our life. Part of the reason for the rarity of dead animals is that so many creatures are devoured by others; and another part of the reason is that there are numerous scavenger animals like sexton beetles and the larvæ of carrion flies which bury or do away with the dead bird or mammal. Deeper, however, is the rôle of Bacteria, which are of great assistance in securing the smooth working of Nature. A dead animal rots; that is to say its tissues are broken down by bacteria and converted in course of time into salts, ammonia and water. What is restored to the soil may soon be absorbed by the roots of plants, and even the ammonia that steals off into the air may be recaptured and brought again into the service of life. Thus bacteria complete a wide circle; they unite dead animal and living plant.

Nutritive Chains.—There are many illustrations of what may be called a nutritive balance between different kinds of animals. Thus gulls often eat fishes, and fishes often eat crustaceans, and crustaceans often depend on diatoms; and some sort of balance must be sustained, year in and year out. A correlation has been convincingly worked out between the catch of mackerel, the abundance of the small crustaceans called Cope-pods, and the density of the marine population of microscopic Peridinid Infusorians, besides the still more minute diatoms, which form a very important part of the stock of the sea-soup. If one link in the nutritive chain is weakened, say the Diatom link by lack of sunshine, the result may be felt at Billingsgate.

It is said that a pound of cod's flesh involves the cod's consumption of ten pounds of large whelk or buckie, and that a pound of this muscular Gasteropod demands for its construction ten pounds of sea-worms: and that a pound of worms is in turn the re-incarnation of ten pounds of microscopic organisms or organic particles. Thus in eating a pound of cod's steak for

dinner the hungry man is devouring a thousand pounds of transmogrified sea-dust; and the world is full of these cycles of re-incarnation or re-embodiment. This illustrates the idea of nutritive chains, which contribute essentially to the Balance of Nature.

This large biological idea of nutritive chains finds many illustrations that affect practical interests. Thus it has been noticed in some parts of Britain, *e.g.*, the "garden of Moray," that the habits of Herring Gulls have changed very much for the worse during the last generation. They have become less markedly fish-eaters and very hungrily vegetarian. They sit on the "stooks" in the harvest fields and gorge themselves with corn. They work up the rows of turnips, scooping out one after another, and pecking at more than they devour, thus opening the way to fungi and thread-worms. How has this change come about ? Part of the answer is that Herring Gulls have become much more numerous. This may be because the natural enemies of the young, such as Sea Eagle and Peregrine Falcon, have disappeared or become rare; or because the eggs are not collected by man so systematically as in former thriftier days; or because some measure of protection has been extended to the adult birds. If it be objected that there are plenty of fish in the sea for all the gulls, the answer is that gulls do not dive and are therefore restricted to fishes swimming near the surface. It is quite possible that around some parts of Britain there are not enough of these to meet the demands of the increased numbers of Herring Gulls. Hence the change of diet.

The sound Natural History objection to any rapid elimination of any type of animal is that it may result in a disastrous disturbance of a long-established balance. To some extent it is good sense to connect a plague of voles and the like with the destruction of the natural checks to their increase, such as hawks and owls, weasels and stoats. This is not the whole story, for climatic cycles have their influence; but it is one factor in the mischief. And it cuts both ways, for it has been shown that the supply of fox skins in Hudson Bay Territory drops when the lemming population is much reduced by starvation or epidemic.

Carnivores and Rodents.—Of great importance in connection with agriculture is the balance between small rodents and small carnivores. An upsetting of this spells disaster. The rabbits in Australia illustrate this tragically, for in main the prodigious multiplication of those that were imported to the great Island Continent was due to the absence of the natural carnivorous checks. The same is true in regard to the calamitous increase of European sparrows in the United States, into which small numbers were imported on repeated occasions, in the hope of countering the attacks of elmtree caterpillars. Whether natural checks are exterminated or were never present is immaterial; and the introduction of new comers into a country where there are no adequate checks will have of course the same results as the elimination of the natural checks in the old country.

Everyone knows the instructive story of the introduction of the mongoose into Jamaica. There are in Africa and India several kinds of these energetic fearless carnovores, which serve a very useful purpose in checking the increase of small rodents and of snakes. To check the imported Oriental rats, which have followed man like a shadow on all his voyages, the mongoose was introduced into Jamaica, where it did good service. It not only counteracted the rats, but it turned its attention effectively to the native "cane-rats," small murine rodents very destructive in the sugar plantations. Having finished with the rodents, the indefatigable carnivores, who had now multiplied considerably, began to attack the poultry and the young of ground-nesting birds. They also attacked certain lizards and snakes, and several species were exterminated. But both the birds and the

reptiles had been playing a useful part in checking the multiplication of various injurious insects, which now began to increase to the great detriment of certain crops. Thus the cure began to evolve a new disease, and this particular case is but one out of many. Consequences are not single, but multiple.

Operating on nature is like playing chess—one has to try to see the distant consequences of a move. Some years ago in the North of Scotland a price was put on the squirrel's head, because of the damage it did in eating off the tops of young forest-trees. But as the squirrel's heads came tumbling in, month after month, for two or three years, all with the forester's approbation, a cloud rose in the sky, just as with the mongoose in Jamaica, for there was an alarming increase in the numbers of wood-pigeons. And these birds are on the black list as far as agricultural interests are concerned. The connexion, far from obvious at first, is that squirrels, vegetarians though they be, are unable to resist the gustatory appeal of the young pigeons they see in the nests on the trees. So the fewer squirrels, the more wood-pigeons and the worse for the farmer.

Birds and Insects.—Of all these natural checks the one that means most to man's interests is that between insectivorous birds and injurious insects. When we think of the legions of plant-bugs (Rhynchota), the hosts of hungry larvæ, such as caterpillars, leather-jackets, wire-worms, the minute Diptera like the Fruit-Fly, the vegetarian beetles like cockchafers and weevils, besides saw-flies and scale-insects, and the frankly destructive tribe of locusts, we realise that their increase is a continual menace to the kingdom of man, which, after all, depends as yet on green plants of the field. If the cloud of injurious insects should thicken for a few years, the consequences would be disastrous beyond telling. Local plagues, now of locusts and again of caterpillars, here of cotton boll weevils there of Phylloxera in the vineyard, hint to us loudly that our whole economic system may be readily imperilled if the natural checks to the multiplication of the injurious insects should cease.

Changeable weather puts an end to many insect-pests; a few commit race-suicide by devouring all the food, but this is rarely possible with field-crops; fortunately for man, insects are often against insects—lady-bird beetles against green-flies and ichneumons against caterpillars, and so on; spiders, frogs, toads, lizards, and other animals do their bit; but on the whole, what matters most is that there should be an abundance of insectivorous birds, for they form the most important of all checks to the multiplication of injurious insects. We do not ourselves believe that there are data for prophecy, but some naturalists of distinction have said that if our insectivorous birds were wiped out—and they are being continually menaced—our whole bionomic system would come to an end within six to ten years. Whether this is or is not a sound prediction, it is absolutely certain that every reduction of birds that feed on injurious insects means a loss to agriculture.

Flowers and their Insect Visitors.—No naturalist can have any antipathy to insects even when they puncture the farmer's and gardener's and colonist's inflated hopes. They are so intriguing, so subtle, so masterful—with as much right to live, if the phrase has any meaning, as any other creatures. They are fascinating even when they are sinister. Many of them are directly beneficial to man, as silk and honey so well illustrate; others like ichneumon flies, are invaluable in checking pests; but the insects that mean most to man are those which secure the cross-pollination of flowers. In search of nectar and pollen, so often advertised by brilliance and colour, by fragrance and form, many insects, such as bees, butterflies, and two-winged flies, visit flowers and unconsciously secure cross-pollination. Without

pollination the possible seeds or ovules cannot in ordinary cases become real seeds that will germinate; and cross-pollination tends to secure not only more seeds but a better quality. Thus one of the most important instances of the Balance of Nature is that between flowering-plants and their insect-visitors. This is not affected by the fact that some of the plants that are most valuable to man, such as cereals, are pollinated by the wind-borne pollen-grains.

We have said enough to illustrate the biological idea of the Balance of Nature. Different kinds of living creatures have evolved together and become mutually dependent, so that increase or decrease on one side of the correlation inevitably affects the other. This is of great practical importance, warning man against upsetting what has been long established and automatically adjusted in Nature. The destruction of insectivorous birds means multiplication of injurious insects; the introduction of rabbits into a new country where their natural enemies are not represented leads to agricultural disaster; the careless introduction of weeds into new surroundings where they are not kept down has often been calamitous; even the apparently irreproachable destruction of poisonous snakes may be soon followed by a plague of small rodents which they helped to keep within bounds. Ignorance is usually very costly, and not least when it disturbs the Balance of Nature.

Man as Balancer.—But we must close with a more positive note, that man, with increasing knowledge, is learning to adjust a balance which he has helped to disturb. Thus, to take a well-known instance, he has been able to cope with the Australian Fluted Scale-insect (*Icerya purchase*) which threatened at one time to put an end to the citrus trees in California. In 1888, Riley and his collaborators imported from Australia a lady-bird beetle (*Novius cardinalis*) which is the native enemy of the Scale, and in less than eighteen months the conquest of the pest was assured. The Fluted Scale-insect has been practically exterminated in California and the United States has sent the effective Ladybird to other Scale-infested countries, such as South Africa and Egypt, with happy results. *In hoc signo laboremus.*

CINCHONA IN THE BRITISH EMPIRE*

THE value of the cinchona tree (*Cinchona Ledgeriana*) as a source of quinine is common knowledge, but the considerable work undertaken by British medical officers in the past in making use of the product of this tree as a preventive against malaria is not so well known. The cinchona tree was introduced into both India and Java between the years 1854 and 1864. Prior to about 1880, the world's supply of cinchona bark was obtained from the native forests in Ecuador, Bolivia, and Peru. It was only after the export of bark from these regions could no longer be relied upon that attempts were made to grow cinchona elsewhere. The British were among the first to succeed in bringing the tree under cultivation. The pioneers were such men as Weddell, Hasskarl, Markham, Ledger, and others, and it was by their efforts that the establishment of important supplies of the drug became a practical proposition.

The early attempts to cultivate the cinchona tree met with considerable success, and private persons took up the business as a commercial proposition. In the early days of cultivation, experiments were made in India, Burma, Ceylon, Malaya, the Sudan, Jamaica, Trinidad, St. Helena, Mauritius, Australia and New Zealand; but these experiments were not always followed up to a definite conclusion. In Ceylon and India the efforts were successful, but private planting was soon given up and the Government has been mainly responsible for the supplies. Within the Empire, therefore, at the present day, India is the only country where cinchona is grown on a large scale. There are Government plantations in the Nilghiris in the south, in the Darjiling district in Bengal (perhaps the best known), and a more recently developed one in Burma. There are also quinine factories both in the Bengal and Madras Provinces.

A recent paper by Dr. J. M. Cowan, of the Indian Forest Service and officiating Director, Botanical Survey of India, and Superintendent of Cinchona Cultivation in Bengal, entitled "Cinchona in the Empire: Progress and Prospects of its Cultivation" (*Empire For. Jour.*, Vol. 8, No. 1 (1929)), discusses the present position of the cinchona and the future prospects of its cultivation.

The enormous importance to the human race within the Empire of the perpetuation of supplies of quinine will become evident when the question of malaria prevention is considered. We have within the Empire a large proportion of the malarial tracts of the world. Prof. Muller of Cologne estimates that some 800,000,000 people suffer from malaria; and according to Sir Ronald Ross there are 2,000,000 fatal cases every year. It is further estimated by Dr. Andrew Balfour that the direct loss sustained by the British Empire due to sickness and death caused by malaria is in the neighbourhood of between £52,000,000 and £62,000,000 per annum.

Apart from financial considerations, it will be apparent that the responsibilities of the British Empire in this question of malaria prevention or reduction are heavy. The question has become an international one, and an organisation for anti-malarial work has been set up by the League of Nations. The policy of this organisation is primarily the quinisation of affected populations. Hence the cultivation of the cinchona tree becomes a question of first importance. It is to a consideration of this matter that Dr. Cowan's paper is devoted.

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* From *Nature* of December 7, 1929.

In India, then, the cultivation of cinchona is confined to Government activities. It was not until 1910-11 that a similar problem had to be faced in Java. Conferences were held, and manufacturers in Holland and growers in Java came to an agreement by which profits were to be shared and by which prices could be maintained at a level which would show satisfactory returns. The disaster which threatened the Java plantations was averted to a great extent by the adoption of this policy; and supplies are now available for the world demands. That the action taken in Java was thoroughly practical, a comparison between the two countries readily demonstrates. They commenced to give attention to the question about the same time and the facilities in both regions were abundant. Yet Java now produces well over 90 per cent. of the world's supply of cinchona bark and India only 4 per cent. A very small percentage of the bark utilised comes from South American forests. The production in India represents only about one-third of the amount actually consumed in the country itself. She is therefore at present not only unable to supply her own demands but also, in common with the rest of the world, is dependent upon the Dutch plantations in Java.

Dr. Cowan explains one of the probelms which has so far guided the cultivation of Cinchona. "It is a well-known fact that to grow cinchona on the same land for a considerable number of years is a difficult and hazardous undertaking, for the first crop, in some manner not altogether understood, renders the soil, at least temporarily, incapable of producing a satisfactory second crop. As long as there is an unrestricted area of forest land the above factor seems of little consequence, but it makes itself felt more and more as the years go on and there is an increasing shortage of land carrying virgin forest."

Dr. Cowan discusses the methods of growing the crop, for details of which the enquirer is referred to his paper. Harvesting the bark commences in a block from about the fourth year, the material consisting of prunings and thinnings. The crop is reaped, the trees being uprooted so as to obtain the maximum of bark, in about the tenth-year. The bark is removed, dried, stored, and then passed on to the quinine factory.

Two problems, in the author's opinion, demand urgent solution: the first is to find additional suitable land, an investigation in which other parts of the Empire should join: and the second is to enhance the output per unit of area. Research work is also necessary with regard to particular strains which yield high percentages of quinine.

The price of quinine is at present very high—£1. 9s. 6d. per lb.—so high as practically to prohibit extensive anti-malarial measures. On this subject the Royal Commission on Agriculture in India in its report (1928) stated: "If India is to embark on any large campaign for fighting malaria, we are convinced that it will be first necessary to reduce considerably the price of quinine within India, and this can only be effected if India is self-supporting in production. To achieve this self-sufficiency a considerable extension to the present area under cinchona will be required . . . . We are satisfied that, in view of the great importance of extending cinchona cultivation and cheapening quinine much more scientific investigation is called for than has been undertaken in the past."

Dr. Cowan has done well in summarising the present position and in pointing out the great importance to a large section of the human race of the development of quinine production.

VALUE TO RUBBER GROWERS OF THE WORK IN LONDON OF THE CEYLON RUBBER RESEARCH SCHEME*

THE demand for rubber arises from its unique physical properties, but the fact that rubber and articles made from it are not as uniform in their qualities as articles made from materials commonly used in engineering and allied industries is a serious handicap in the way of more extended application. It is the aim of the work in London to improve the uniformity of rubber with a view to promoting a wider sphere of usefulness, lower manufacturing costs in Europe and America, greater sales of rubber articles and an improved demand for the raw material.

For this purpose a study is being made of the effect of plantation practice on the more important properties of rubber. The information obtained is useful to the rubber grower not only because it ensures that methods of preparation are fundamentally sound, but also because the more thoroughly the behaviour of rubber is understood, the easier it is to control, resulting in cheaper manufacturing costs, a wider scope and an improved demand.

The practical value of this procedure is illustrated by reference to the work on problems connected with vulcanisation which received a considerable amount of attention several years ago. At that time manufacturers were handicapped in their use of plantation rubber by serious variations in vulcanising properties, and there is no doubt that the work of plantation chemists, by providing a wealth of knowledge concerning the factors involved, did much to remove a difficulty which at one time seriously militated against the use of plantation rubber.

Since then many changes have occurred in manufacturing practice in Europe and America and problems connected with uniformity have grown more complicated. More than one property requires consideration before a sample can be pronounced free from abnormality. A detailed investigation of this question has been made in London, as a result of which it is considered that more active steps may now be taken to obtain intrinsic uniformity in the East. For this purpose it is proposed to study the product of all rubber producing units in Ceylon and to carry out investigations *in situ* with a view to suggesting a remedy where abnormalities are found.

PLASTICITY

With the development of modern methods of manufacture new difficulties have arisen in the use of plantation rubber. For this reason problems connected with plasticity now occupy a prominent position in the programme of work in London. A considerable amount of difficulty is experienced by many manufacturers in plasticising and moulding to shape some consignments of first grade rubber, but the same difficulty is not experienced with crudely prepared material such as the lowest grades of rubber. If an appreciable amount of low grade rubber or reclaim is mixed with the best grades the difficulties of manipulation are decreased. Consequently the poor and irregular plasticity of some consignments of first grade crepe and sheet interferes with the demand for carefully prepared rubber and improves

* By Mr. G. Martin, B.Sc., A.I.C., F.I.R.I., Chemist and Superintendent in London of the Ceylon Rubber Research Scheme. A memorandum elaborating the statement made by him to the Executive Committee of the Scheme in July, 1929, and submitted to and approved by the London Committee on 31st January, 1930.

that for crudely prepared material. Interested parties sometimes assert that the quality of first grade rubber is improved by mixing with it a certain amount of reclaimed rubber, because the latter being soft and tacky enables the new rubber to be worked more easily and to be mixed more thoroughly with the necessary compounding ingredients. If regular and large supplies of first grade rubber of satisfactory plasticity were forthcoming it would undoubtedly increase the value of well-prepared material compared with that of reclaim and crudely prepared rubber. Moreover, if the whole of the better grades of plantation rubber were uniformly plastic, they would lend themselves more readily to developments in manufacture which are essential to the progress of the industry as a whole.

Considerable progress has been made in London with the investigations on plasticity. When the study of this question was commenced at the Imperial Institute by the London Staff of the Ceylon Research Scheme little was known about the subject apart from general experience. From a crude and unreliable method of determination one has been developed which promises to be quick and accurate and, in the opinion of the London Staff, a marked improvement on methods employed elsewhere. This has involved a considerable amount of work which was only completed last year.

A preliminary examination of the extent of variability in plasticity of rubber from about twenty-five estates in Ceylon showed that it was appreciable, and the effect on plasticity of a number of factors in preparation was accordingly studied. Two important conclusions have so far been arrived at, (1) the use of sodium bisulphite has an appreciable hardening effect, and (2) the conditions under which rubber is stored in Europe, may have considerable influence upon plasticity. Investigations are still proceeding with regard to the effect on plasticity of factors in preparation, and arrangements have been made for the effect of conditions of storage to be more fully explored. Preliminary experiments also showed that machine-dried crepe was more uniformly plastic than other grades of crepe and sheet, but this will require confirmation by many more experiments before it can be definitely accepted.

The possible effect of this work on factory practice in the East is naturally of considerable interest to the rubber grower. There are many possibilities of which the most obvious is that a demand might arise for a particular type of rubber such as machine-dried crepe, or, as it is proposed to ascertain which estates are supplying rubber with abnormal properties and to study the preparation of rubber on these estates, the work may lead to recommendations for the modification of methods of preparation on individual estates.

It must be remembered, however, that other organisations besides those of the rubber producers are working on problems of plasticity, and judging from the parallel case of vulcanisation it is expected that the work of chemical manufacturers on softeners, of rubber manufacturers on manipulation, of reclaim manufacturers on the perfection of their product, and of rubber producers on causes of variation will eventually lead to a method of control which, although it may not revolutionise present procedure in the East, will nevertheless increase the usefulness of rubber and improve the value of the better grades of material.

INVESTIGATIONS SOLELY FOR THE BENEFIT OF THE PLANTER

No attempt is made in this outline to give detailed reasons for each item in the programme of work. Rubber is the basic material of a wonderful assortment of manufactured articles involving different conditions of manufacture and service, and calling into play different properties. It is not a simple matter to decide which properties can be studied with the

greatest advantage, but the close co-operation between planters and manufacturers on the London Committee has been of considerable value in enabling the staff to arrange that their tests shall be of the maximum utility. For this purpose it has been necessary to devote some time to a study of what may appear at first sight to be manufacturing problems such as the control of mastication, vulcanisation of technical mixings, and the ageing of vulcanised rubber. As explained in the introduction the sole object of these investigations is an improvement in the demand for first grade plantation rubber; they are therefore of considerable value to the rubber grower and require study from his point of view. The work on mastication was undertaken in order that the results of plasticity tests should have the greatest practical value. The work on the vulcanisation of technical mixings has made it possible to classify the different types of variation encountered in manufacturing practice and to carry out investigations to obtain uniformity. The work on the ageing of vulcanised rubber has prevented the approval of samples which gave satisfactory results when tested soon after vulcanisation but which had poor ageing properties and might have given poor service. For example, in connection with the study of the quality of air-dried sheet now receiving so much attention in Ceylon it was shown that one darkening agent tried was unsuitable and that drying without smoke under certain conditions might give undesirable properties.

It will be seen that many considerations enter into the reasons for investigations in London. Although the objects may not always be apparent to those who are not familiar with manufacturing operations it cannot be too strongly emphasised that no investigation is carried out by the staff in London unless it will directly or indirectly benefit the rubber grower.

COMPETITION BETWEEN RUBBER AND OTHER MATERIALS

Although plantation rubber is in the fortunate position of having no serious rival at present with regard to its principal use (rubber tyres), there are a number of uses where competition already occurs.

A recent newspaper article by John Haworth, Secretary of the India Rubber Manufacturers' Association, states: "In practically every branch rubber is faced by competition of products which fulfil the same functions, although not so efficiently." In order to meet this competition attention is being given in London to the determination of the technical factors which hinder the use of plantation rubber for specific purposes and endeavours are being made to ascertain whether special types can be prepared which will give the necessary measure of superiority over alternative materials. In this connection investigations are proceeding with a view to increasing the usefulness of plantation rubber with respect to (a) ebonite, which has to compete with synthetic products and (b) tape and thread for which fine hard Para is still frequently used. With regard to the investigations for the improvement of ebonite, the Rubber Research Scheme is co-operating with the Research Association of British Rubber Manufacturers and the Electrical Research Association.

In conclusion, the work in London is designed to improve the usefulness of plantation rubber by preventing the adoption of unsound methods of preparation, by increasing uniformity, by encouraging and extending the use of first grade material, and assisting it to meet competition from alternative products.

IMPERIAL INSTITUTE,
SOUTH KENSINGTON,
S. W. 7.
February, 1930.

A SHORT REVIEW OF THE PRESENT POSITION OF THE PLANTING OF BUDDINGS OF PROVED CLONES*

QUESTIONS relating to the distribution of buddings in the field have received a considerable amount of attention during the past two years. To make the position more clear a *résumé* of the advice which has been given from time to time on this subject may prove useful.

Some six years ago Dr. Heusser, of the A.V.R.O.S. Experiment Station in Sumatra, published the results of his first tapping experiments on budded trees (1923). The results obtained with certain clones were so promising that it was advised that the future planting material should consist of an equal mixture of buddings of the best clones and seedlings from the best available mother tree seed. At that time buddings had not been tapped for a sufficiently long period to justify planting them on a commercial scale without the precaution of mixing them with seedlings.

At the present time the position has changed considerably; the results of subsequent tapping tests over a period of six years have borne out the promise of success indicated in the earliest experiments. For certain clones, *e.g.*, AVROS clones 49 and 50, long records are available. Of equal importance with the high yielding properties of such clones early doubts as to the future behaviour of budded trees with regard to bark renewal, resistance to disease, and liability to mechanical damage have been dispelled to a great extent.

It is important to bear in mind that the planting of seedlings mixed with buddings was advised as a precautionary measure. In the event of the budding proving unsatisfactory in later years it was considered that this policy would allow of their removal leaving the area still fully planted with seedlings of good quality.

Since it has been proved beyond reasonable doubt that a uniformly high yielding stand of trees can be established by planting with proved clones the interplanting of seedlings is now unnecessary. Experience has shown that the yields obtained from so-called selected seedlings (the seed produced by high yielding mother trees, the male parent being unknown) are lower and much more variable than the yields obtained from buddings of good proved clones. Furthermore, the practice of mixed planting even as a precautionary measure has obvious disadvantages. In an area established on such a plan there will be a few seedlings of high yielding capacity which it will pay to keep at the expense of a few of the buddings, but these seedling trees can only be determined by laborious individual yield tests. This would necessitate leaving all trees, except obviously diseased and weakly specimens, for at least one year of commercial tapping, *i.e.*, until about the sixth year from planting. At this stage the thinning out of alternate trees would be a costly operation and considerable damage to the remaining trees would be unavoidable. During the whole of the period of six years the close planting (200 to 250 trees per acre) required by the system would have impaired the general growth. Since budded trees in their later years are generally a little less vigorous than non-budded trees, they would probably suffer most from the over-crowded conditions.

A further complication arises in the tapping of buddings and seedlings in the same area. The bark of a budded tree, at least in its early years, does not usually show the heavy development of outer corky tissues characteristic of the lower portions of the trunk of a seedling. This fact gave rise to the early, exaggerated reports that budded trees produced a thin

* By C. E. T. Mann in *Rubber Research Institute of Malaya—Quarterly Journal*, Vol, 1, No. 4, December 1929.

bark which was hardly tappable. Actually the latex producing region of the "cortex" of a good budding is generally rather thicker than that of a good seedling. The absence of the thick outer corky layer does, however, make more careful tapping essential. To attempt to modify the tapping in a mixed area of buddings and seedlings so that both types of the tree will be correctly tapped will be extremely difficult.

These defects in the system were no doubt realised at the outset and it is not surprising therefore, as soon as sufficient data on the later performance of buddings became available, that the practice was no longer advised. The planting of buddings of good clones only, well intermingled, was advised for future development. But still a note of caution crept into this advice. Areas were to be planted with proved clones of which tapping records were available for two or three years, and the clones were to be mixed. In large areas as many as ten clones were used in this way, sometimes in equal proportions but frequently with larger proportions of most promising clones.

Recent work on the tapping of budded trees has shown that different clones behave very differently when tapped on a uniform tapping system. Certain clones reach their highest yield six days from the commencement of a tapping period; others reach their maximum yield at a much later period. There is, in fact, very strong evidence that, to get the best yield from a clone, tapping will have to be carried out for definite periods with definite intervals of rest and these periods will differ for different clones. Such treatment would be practically impossible in a mixed planting of proved clones.

Either, only clones of similar yield performance should be mixed in a given area or, planting should be carried out in blocks each of a single clone if full advantage is to be taken of the individual yield characteristics of each clone. To be in a position to adopt such a policy more information is required on the behaviour of a large number of the promising clones at present available. Comparatively few clones have been tested over a sufficiently long period to justify their use in pure plantings. Many of the more recently established clones show promise of giving better results than those developed in the early days of budding. For the present therefore the desire to include promising newer clones with the best of the older established clones will generally lead to the adoption of a policy of mixed planting. During the development of the young areas thinning out will be based on the results of continued observation and recording of the original budded trees of each clone. Should the oldest buddings of a particular clone develop a serious defect in later years it will be possible to remove the young budding of this clone from more recent plantings. The increased space made available may be utilised by the buddings of more satisfactory clones.

Applied to plantings consisting entirely of buddings of the oldest proved clones this argument loses much of its force. It seems unlikely that buddings of a high yielding clone, which has a satisfactory record over a period of ten years or more, will suddenly develop a serious defect. In such cases it may be decided to take the risk of such a possibility and, by planting sufficiently large areas each with a single clone to reap the fullest advantage from the trees when they come into bearing. It seems unnecessary to stress the practical advantages of the system from the point of view of establishment and maintenance. In the event of the failure of a clone the question to be decided appears to be whether it is better for the loss which this will entail to be evenly distributed throughout the whole area planted or whether to confine the possibility of loss to a particular portion of the area sufficiently large to allow successful replanting in the extreme case.

Though block planting or pure planting of clones has already been adopted to a small extent, the question is raised in this article in order to indicate the trend of recent development in budding practice.

BUDGRAFTING AND SEED SELECTION WITH RUBBER

DEPARTMENT OF AGRICULTURE, CEYLON LEAFLET No. 58

INTRODUCTION AND POLICY

THE purpose of this leaflet is to bring to the attention of rubber growers in Ceylon the considered policy of the Department of Agriculture on the testing, provision and use of superior planting material in rubber, and to supply brief practical hints for planters who wish to open new areas with budgrafts. The policy of the Department is described in the memorandum which was placed before the Estate Products Committee on September 10, 1929. The memorandum is as follows:

"From time to time plans for the development of the Iriyagama Division have been laid before the members of the Estate Products Committee for approval, and it is now necessary to consider certain decisions regarding the work of the Iriyagama Division and the policy to be adopted by the Department of Agriculture in matters connected with rubber budding and seed selection. The decisions in question are noted below. They have been made by a sub-committee which was representative of both the Department of Agriculture and the Rubber Research Scheme. The appointment of the sub-committee arose partly out of the necessity for meeting certain criticisms of the budding work in progress and partly out of the necessity for modifying plans of work according to information and views brought from the East by Mr. Lord, Economic Botanist of the Department of Agriculture, who returned in June from a tour of inspection. The sub-committee referred to consisted of the Hon. Major Oldfield, Messrs. C. E. A. Dias, L. P. Gapp, L. Lord, R. A. Taylor (of the Rubber Research Scheme) and J. Mitchell (as Secretary) with Dr. W. Small as Chairman. The name of Mr. H. W. Roy Bertrand was afterwards added to it. It is perhaps the case that the appointment and terms of reference of the sub-committee should have been reported to and approved by the Estate Products Committee, before it began its work, but it has to be pointed out that the matters placed before the sub-committee were of an urgent nature and that the sub-committee contained among its members the four members of the Estate Products Committee who were appointed last January to consider certain questions relating to the work of the Iriyagama Division.

The decisions referred to are as follows:

IRIYAGAMA DIVISION

(1) *Mother trees to be tested at Iriyagama.*—(*a*) The following Peradeniya and Heneratgoda trees to be tested—ESP 12 and 5, H 2, 24, 400, 401, 440, 445, 439, 411, 75, 82, 47, 26, 21, 140, and 203. (*b*) Also W 120 and M 162 (Mr. Dias), Hillcroft 34 (Mr. Gapp). (*c*) A further selection of mother trees from those offered by Major Oldfield and from those of which bud-wood is available at the Nivitigalakele Station of the Rubber Research Scheme, the selection to be made by Mr. Lord and Mr. Taylor.

(2) *Foreign clones to be tested at Iriyagama.*—Among others Tj 1, 8, and 16, BD 5 and 10, AVROS 49, 50, 256, and 71, SR 9, PB 23, Ct 88, H 2 to be tested with the foreign clones as a control.

(3) *Size of clones, &c.*—The size of the clones under test to be reduced to 60 trees in place of the 120 previously arranged, the clones to be in 12-tree plots in randomised blocks with a border row of H 2 or of seedlings round each test. Seedlings in 24-tree plots to be included in the trials of clones (here also in 24-tree plots) in area 1 in order to test yields of seedlings against yields of bud-grafts.

(4) *Records.*—Steps to be taken to secure as complete yield records as possible of the mother trees in use (see General Recommendations (2) below).

(5) *Stock and Scion.*—A test of scion on its own stock against the same scion on vigorous mixed stock to be made, the test to be regarded as a general attempt to find out if stock influences scion rather than an attempt to show which particular stock will do best with a given scion.

(6) *Numbering of budgrafts.*—Terraces to be lettered and the holes to be numbered consecutively along the terraces. Where lettering of terraces is not possible holes to be numbered consecutively throughout the area.

(7) *Policy in procuring budwood for use at Iriyagama and in disposal of products.*—(*a*) Budwood of desirable mother trees to be purchased if it is not given free. (*b*) All future requests for free budwood from estates to be accompanied by an undertaking not to dispose of the products of such budwood or of the clones derived from it until the completion of two years' test tappings of the clones. (*c*) Estates which have supplied free budwood to be kept informed of the results of tapping tests of clones derived from their mother trees in order that they may lay down multiplication nurseries for budwood if the tests show good results. (*d*) Estates supplying budwood to be informed that the Department of Agriculture may wish to use the budwood in the establishment of seed gardens for selection work. (*e*) In the case of budwood which is purchased from estates, the Department of Agriculture to be at liberty to dispose of the products in any way that may be considered desirable. (*f*) Products of budwood supplied free to be disposed of in accordance with the provisions of (*b*) and (*c*) above.

(8) *Policy in testing clones of local mother trees at Iriyagama.*—(*a*) Results of test tappings of clones at Iriyagama to be published periodically and the Department of Agriculture to be empowered to issue certificates of approval when results justify the issue. (*b*) Approval of mother trees to be made known for the guidance of the public and the benefit of the estates concerned after one year's supervised tapping tests.

GENERAL RECOMMENDATIONS

(1) *Policy in tests of clones of local mother trees carried out on estates.*—(*a*) Arrangements to be made by the Department of Agriculture for the supervision of tests of clones on estates if the estates in question express a desire for such supervision. (*b*) When supervision is exercised, the Department of Agriculture to publish the results of test tappings for general information.

(2) *Procedure in the selection of high-yielding trees for mother trees.*—(*a*) A preliminary selection to be made of trees reported by tappers or overseers to be high-yielders. (*b*) The yield of latex of the selected trees to be measured for twelve successive tappings. (*c*) Incomplete tappings caused, *e.g.*, by wet weather to be excluded from the records. (*d*) The trees to be tapped on the same days and, if possible, by the same tapper. (*e*) After the preliminary work mentioned, the trees to be inspected by the Department of Agriculture for selection for further tapping tests. (*f*) Selected trees then to be tapped for a full tapping season by, if possible, the same tapper; the latex to be coagulated after each tapping and converted into dry rubber, the records of each tree to be kept in a special book for

the inspection of the Department of Agriculture; incomplete tappings to be excluded from the records. (*g*) A record of the height and length of the tapping cut at the beginning and end of the season to be kept. (*h*) Records to be expressed when complete as "yield per tapping" and a final selection of mother trees from the tested trees to be made on this basis. (*i*) Trees under test to be inspected at intervals by the Department of Agriculture. (j) Only trees which show a yield of not less than five times the average yield of the field in which they are situated to be considered as suitable for mother trees.

(3) *Policy in testing mother trees which develop brown bast and bark rot.*—Tests of clones derived from mother trees which have developed brown bast or bark rot to be continued. It is felt that these diseases are preventible and that the present knowledge of their inheritability does not justify the cessation of tests of affected mother trees.

(4) *Seed gardens.*—Seed gardens for seed selection work to be established with one, two, and four clones, and steps to be taken to acquire the necessary areas.

(5) *Identification of local clones.*—Steps to be taken by the Department of Agriculture to record the seed and leaf characters of local mother trees.

(6) *Budwood and seed for small-holders.*—Twenty-five per cent. of the budwood and seed produced by the Department of Agriculture and by seed gardens to be reserved for small-holders if they shall express a wish to obtain improved material.

(7) *Land for further experimental work.*—Steps to be taken to acquire land to replace the land at Paspolakande which is not now available.

(8) *Propaganda work and publications.*—Steps to be taken to impress upon estate authorities the necessity for rubber budding and selection work; to prepare for circulation a leaflet which will embody the above decisions and will make clear the steps that ought to be taken and the conditions on which the Department of Agriculture will render advice and assistance in budding and selection work."

PLANTING

For estates contemplating planting new or replanting old areas, the following brief hints may be useful. Planting may be done either with mixtures of proved clones only or with mixtures of such clones together with alternate rows of selected seedlings. With the present experience of budgrafts there would seem to be little point in including seedlings unless they are from seed of very high-yielding trees. One method of planting is to have plants 15 ft. by 15 ft. (193 trees per acre) with the different clones running along the diagonals. This allows of complete clones being cut out after the first year's tapping. In any event the stand of 193 trees per acre should be reduced to 100-120 within five or six years. At least five clones should be used. At present no Ceylon mother tree has yet been proved but proved Dutch and Malayan clones are available. In addition to the foreign clones mentioned in the first section of this leaflet, AVROS 163 and 152 may also be included, if desired, in planting programmes. The clones recommended here comprise some of the best planting material available at present. As further tappings of these and of other clones become available the list may have to be amended.

Budgrafts frequently put out lateral branches low down on the stem. Such branches appearing within six feet of the ground should be thumbed off when young. This height is recommended as it may be found economical to tap budgrafts on two cuts.

The best method of tapping budgrafts has not yet been found either by experience or by experiment. If, as is held in some quarters, high-yielding trees are more susceptible to brown bast some modification of the normal Ceylon method of tapping may be necessary. By the time the question arises in Ceylon the Department of Agriculture will be in a position to issue recommendations.

HOW TO OBTAIN PLANTING MATERIAL

At the moment Malayan and Dutch material has to be imported. It may be imported either in the form of budwood or as budded stumps. If arrangements are made to have budwood shipped immediately after cutting and to be taken to the estate and budded immediately on arrival in Colombo, budwood from as far away as Java will give a satisfactory number of successes, but the purchase of budded stumps is perhaps safer. A list of firms suppling budwood and budded stumps may be obtained from the Director of Agriculture.

The purchase of sufficient stumps to plant an area of budwood to bud an area in the field is costly. One way of providing material for field use is to purchase stumps or budwood to form a budwood multiplication nursery. In a year after planting or budding each plant on good soil should produce at least two yards of good budwood with, it may be estimated, fifteen buds to the yard.

Stumps in budwood nurseries should be spaced 3 ft. by 3 ft. and for the first year it is considered advisable to allow only one shoot to grow. In the second year, after cutting and using the budwood at the end of the first year, two shoots (or branches) may be allowed to grow. Supervision is necessary to see that the shoots growing are actually produced by the scion and not by the stock. A budwood nursery should be well manured, if necessary, to encourage vigorous growth.

BUDDING

The operation of budding can rapidly be learned by intelligent coolies. At least two excellent text books* on bud-grafting have been published and a short account of the methods in use in the Dutch East Indies has appeared in *The Tropical Agriculturist.*† The Department of Agriculture has a small number of trained budding coolies who may be sent to estates for short periods to demonstrate the actual operations.

The materials necessary for budding are budding knives, waxed bandages, labels and one or two old rags. These are conveniently carried by each budding cooly in a small tray or box. The bandages are made of longcloth in the following way: "entwas" is melted in a cylinder about 23 in. high and 4-6 in. diameter by standing the cylinder in boiling water. The roll of longcloth is torn into strips 20 in. long and of the width of the

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* *Practical Bud-grafting and Seed Selection of Hevea Brasiliensis* by H. Gouch; Kelly & Walsh, Singapore.

The Budding of Hevea in Modern Plantation Practice by F. Summers, Rubber Research Institute of Malaya.

† October, 1929.

roll. These strips are then loosely rolled into cylinders 20 in. long and dipped for about half an hour in the melted entwas. After removal from the wax and when the wax has set bandages about $1\frac{3}{4}$ in. wide are torn from the waxed cloth. One or two bandages are necessary per tree.

Budding may take place either in the field or in the nursery. Budding in the nursery is recommended as supervision can be more thorough and only good stocks need to be used. Even if four seeds or stumps per hole are planted in the field it may happen that none of the resulting plants in some holes is really vigorous. Budding should be done on vigorous stocks and in order to ensure such stocks being available the nursery should contain four times as many plants as are actually needed. The best plants are then chosen for budding. Stocks should be not less than 1 in. diameter at 2-4 in. from the ground.

It has been found at Peradeniya that entwas bandages unless carefully applied may become loose during heavy rain. A precaution is to tie the leaves used as shade for the bud in such a way that the bandage is also kept tight.

ADVICE TO PLANTERS

The Director of Agriculture will be glad to give advice and render any assistance in his power to planters desirous of opening new areas or replanting old areas with budgrafted rubber. Members of the Rubber Research Scheme can receive advice and assistance from the Scheme.

DEPARTMENTAL NOTES

PROGRESS REPORT OF THE EXPERIMENT STATION, PERADENIYA

FOR THE MONTHS OF MARCH AND APRIL, 1930

TEA

MANURES were applied to the plots under *Indigofera* as per programme in April.

Plots 163, 164, and 166, which were not pruned last October when due were pruned in April. The style of pruning adopted is much lighter than the pruning done in the *Indigofera* plots. Increased incidence of shot-hole borer has been noticed in these plots which are 6 months overdue to prune.

In plots 141 to 145, holes for supplies dug about 3 months ago were filled in. A small quantity of *Indigofera* was buried in the bottom of each hole. All the holes had become completely covered with *Indigofera* and the work of first clearing away the cover crop in order to lay bare soil for filling considerably increased the cost of the work. The increased cost, however, is compensated for by the superiority of the material for filling.

Albizzias in plot 150 were thinned out and the remaining trees lopped.

RUBBER

Tapping of the New Avenue Rubber manurial experiment started on April 1st. The manures were applied to the plots in January and during March two inspections were made with a view to noting the effect of the manuring on wintering. On both occasions it was observed that the manured plots retained their old leaves longer than the control plots but that the colour of the new foliage was darker and healthier than that of the control plots. The tendency of manured rubber to winter later has been recorded by Dutch workers.

In plots 151-154 (approximately 4 acres) it is intended to carry out a second rejuvenation experiment. As the plots contain a number of trees that have never been tapped, however, it is necessary to obtain first a year's representative yield, and tapping for this purpose was started on April 2nd.

Measurements of untapped and renewed bark were taken in the change over experiment in the no-change-over plots and the change-over-yearly plots. Measurement of the change-over-six-monthly plots is not due till October and comment will therefore be reserved till that measurement has been taken.

CACAO

On account of pressure of work pruning has this year been limited to the removal of suckers and dead wood. This operation was completed in April. A round of bark canker treatment was also completed.

A large number of shade trees (*Erythrina umbrosa*) have been blown down this year causing great damage to cacao by their fall as well as by the sudden removal of shade. These trees form very shallow root systems and the number of trees blown down in the last few years has been

enormous. This poor root system constitutes a great drawback to the use of this tree in cacao.

CATTLE

Five young Kangayam animals were transferred to the Northern Division, four to Paranthan and one to Jaffna.

THE IRIYAGAMA DIVISION

In area 6 (foreign clones) 24 vacancies were supplied. Dry weather followed and the plants had to be watered.

The bush green manure plants in this area were lopped.

It was noticed that a number of young budded plants showed a tendency to branch at an early age. Such branches were removed and a count was made of the plants treated in order to ascertain if this was a characteristic of any particular clones. It was found that by far the greatest number of cases had occurred in Tjirandji 1 and Tjirandji 8. A complaint has also been received from an estate of early branching of Tjirandji 1.

Copies of the plan made by the Survey Department showing the position of every hole were received in March. Three areas of 10 clones each have been laid out on the plan for budding, or planting with budded stumps, this year. The plants which will form the border rows round these areas have been marked with a white band and all vacancies in border rows have been re-holed for supplying in the south-west monsoon.

Of the new areas, areas 1 and 3 have been laid out to include the largest number of well grown plants fit for budding in the field this year. Area 2 will be used for the trial in which half the buds in each clone are put on to stocks grown from seed of the same tree and half on to mixed seedlings. For this purpose it is necessary that all budding should be done in the nursery and therefore the land containing the fewest good plants has been chosen for this area. All existing plants will have to be uprooted. It is intended to take all the best plants from this area to fill vacancies in border rows of seedlings this south-west monsoon.

These three areas with their border rows will only occupy something like half the terraced and planted land. In the remainder of the clearing the plants will have to be pulled up and thrown away this year. The reason for this regrettable waste is the reduction of size of clones from 120 to 60 trees by the last committee concerned with the plans of this Division with the result that there are at present not enough mother trees to utilise the land opened. There is no obvious alternative however, the plants are mostly two years old, they are too big to sell and they will be too big to bud next year.

Good progress has been made with fencing and with the extraction of stumps.

The terracing of area 7, a new area for the reception of the remainder of the foreign clones selected for the testing which are not as yet planted out was completed in April. *Gliricidia* cuttings, have been planted opposite each hole and the banks of the terraces have been sown with a mixture of *Calapogonium mucunoides* and *Centrosema pubescens.*

T. H. HOLLAND,
Manager,
Experiment Station,
Peradeniya.

INTERNATIONAL CONGRESS OF TROPICAL AGRICULTURE, ANTWERP, 1930

AN International Congress of Tropical Agriculture is to be held at Antwerp from July 28-31, 1930 at the Palais des Congrès. It has been organised by the Association Scientifique Internationale d'Agriculture des Pays Chauds. Previous Congresses organised by this Society were Paris 1908, Bruxelles 1911, London 1914, Seville 1929. Another is to be held in Paris in 1931.

Manuscripts of papers to be presented at the Congress should be addressed to the General Secretary, M. C. Huffmann, Rue, Royale 230, Bruxelles, before June 1st. Manuscripts should be accompanied by a résumé not exceeding a page of manuscript. This résumé will be translated into French, Dutch and English and sent to the members of the Congress before July 1st. Papers may be written in French, Dutch, English, German, Italian, Spanish and Portuguese.

Discussions on the papers can take place in the same languages. Translators will assist at the sittings.

DUST-SPRAYING MACHINES

THE Mycologist to the Rubber Research Scheme who has carried out sulphur dusting experiments on Kandanuwara Estate against *Oidium* leaf disease is hoping to try at an early date an English dusting machine. The results of these trials will be interesting and it is suggested that estates which contemplate undertaking sulphur dusting should await the completion of them before deciding what type of a machine to buy.

REVIEWS

COFFEE GROWING IN EAST AFRICA*

A hearty welcome should be extended to Mr. J. H. McDonald's book on coffee growing in East Africa. It contains the kind of information the practical man requires and the scope of the work is comprehensive of all aspects of coffee growing. The author does not put forward his opinions in a dogmatic manner but attempts rather to inculated a spirit of enquiry and experiment. He gives credit for the work done by East African Departments of Agriculture and he directs attention to the bearing of their work and results on the problems of the coffee planter. Mr. McDonald's point of view is sound because it is scientific, and he is to be congratulated on the result of his self-imposed task of collecting and collating the scattered information he set out to make available. The publishers of *East Africa* are also to be congratulated on the printing and get-up of a book issued under their aegis. The present reviewer does not wish to suggest that Mr. McDonald's book is not worth the price asked for it, but he will not be alone in saying that he would welcome a smaller charge.

A large proportion of the book is devoted to the diseases and pests of coffee. The chapter on *Hemileia vastatrix*, the fungus of coffee leaf disease, is comprehensive and interesting, but it may be doubted if the conclusions of the writer (Mr. Alleyne Leechman) will meet with universal acceptance.

It is inferred that the collapse of coffee in Ceylon which followed the spread of leaf-disease in the 'seventies and 'eighties was really due to bad agricultural methods, the presence of an indigenous coffee (*Coffea travancorensis*) and to want of immunity towards leaf-disease in Ceylon coffee. The first two of these points have been criticised by Mr. Frederick Lewis in *The Times of Ceylon* of March 25, 1930. With regard to the third, East African coffee is supposed to have acquired immunity to *Hemileia*, and much comfort for East African coffee planters is derived from the supposition. It is perhaps possible and probable that coffee in East Africa has acquired or is acquiring immunity to *Hemileia*, but has the possibility been proved beyond doubt ? Has it been shown with regard to coffee and *Hemileia* that the host plant may acquire or lose the power of resistance to the parasite ? Is the supposed acquired immunity to leaf-disease transmissible from parent plant to offspring through the seed ? In a question of immunity or susceptibility to disease is the parallel between the coffee tree and the human being a valid one ? Clean cultivation is recommended as a measure to be adopted in the fight against leaf-disease and, as far as noxious weeds are concerned, no fault can be found with the recommendation, but it is hoped that clean cultivation means more than a scraping of the surface of the soil with a *jembe* or mammoty. The attention of the East African coffee planter may be directed to the value of selective weeding, that is, the use of weeds which are not harmful to the major crop and are at the same time useful and valuable as preventives of erosion when growing and as improvers of conditions of moisture and fertility when incorporated with the soil.

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* *Coffee Growing: with special reference to East Africa.* By J. H. McDonald. (London: published by *East Africa*, 1930). Price 21s.

Mr. McDonald rightly stresses the benefits of and the necessity for green manuring, but students of the recent developments of tropical agriculture in the east will be struck by the lack of mention in his book of contour planting, contour platforms, terraces and hedges of green manure plants, and systems of drainage and silt-pitting. The important subject of soil erosion does not seem to loom large on the horizon of the East African coffee planter and it is to be hoped that he will not have a rude awakening when it is too late to remedy matters and to replace his lost top soil. It is true that he has a smaller rainfall than the tea or rubber planter of Ceylon and that he plants his coffee on slopes which are on the whole more gentle than those of the estates of this island, but now is the time to draw attention to the necessity for preventing the downward movement and loss of top soil, especially the fine clay fraction, and for ensuring the maximum absorption of rain water by the soil and the controlled removal of surplus water. Experiment with ground cover plants which will prevent the beating action of rain and the run-off of surface water, systematic digging in of green material which will increase the humus content and the absorptive capacity of the soil, drains and silt-pits which will increase absorption, control the movement of surplus water and trap eroded soil so that it can be returned to the land may be recommended, and emphasis may be laid on the close connection between measures of soil conservation and the maintenance of soil fertility. It is not too much to expect that experiment on the lines mentioned will lead directly to a smaller incidence of the pests and diseases of coffee in East Africa and to a reduction in the space given to them in future editions of Mr. McDonald's book. It may be added that there is room for intensive investigation on modern lines of the problems of coffee cultivation in East Africa and it is hoped that arrangements will be made to establish the research institute which has been suggested and discussed by the planters.

Mr. McDonald's book is of value to Ceylon agriculturists who are interested in the revival of coffee growing. It is concerned primarily with *arabica* coffee rather than *robusta* but it contains information concerning both kinds and it makes clear the conditions required for each with special reference to the important question of elevation.—W.S.

LATEX TUBE BORE

IN the *Tropical Agriculturist* for March 1929 was reproduced the report of a lecture by Mr. H. Ashplant, the rubber specialist, United Planters' Association of South India, delivered to members of the Rubber Growers' Association in London. In this lecture it was claimed that the bore or diameter of latex tubes in *Hevea* was markedly correlated with the yield and that it was a relatively simple matter to determine with approximately 80% efficiency, which plants in a nursery 6 months old would develop into high-yielding trees. Certain figures were given in support of this statement but beyond an indication that the measurements of latex tube bore were obtained from thin sections of the petioles or leafstalks no details of technique were given. In an editorial note accompanying the article the writer drew attention to the possibilities of such a method of selection but pointed out that insufficient details had been given and stated that "it is to be assumed that Mr. Ashplant has evidence for his statements, but until full data are published and contributory experiments carried out elsewhere, confirmation of his theory must be withheld."

Dr. A. Frey-Wyssling of the General Experiment Station of the A.V.R.O.S in Sumatra has published in a full paper* the results of his investigations into the relation between the diameter of the latex tubes and the rubber production of *Hevea*. He shows that, from theoretical considerations, the diameter of the latex tubes should affect markedly the yield. A full description of the technique used in obtaining the measurements of latex tube bore is given and this is followed by a lucid description of the anatomy of the *Hevea* petiole or leafstalk. He states that the latex tube bore in one tree is constant and that the average of the two lots of 100 measurements agreed within the limits of standard deviation. So far so good. In an examination of the petioles from trees of selected clones in which the variations in yield were not very great it was seen that the differences in latex tube bore were not sufficiently great to classify the clones according to the diameter of the latex tubes. It was therefore resolved that measurements of the tube bore of seedling trees should be taken in order to determine if differentiation could be made. A difficulty had to be faced: "Investigation of tappable seedlings cannot decide the most important problem, to wit, whether Ashplant's method of selection is applicable to nurseries. On the other hand comparative measurements can be carried out in leafstalks and bark, and the correlation between *yield* and *number of rings of latex tubes* can be contrasted with that between *yield* and *diameter of latex tubes.*" Seedling trees 8 to 9 years old were used and averages of 100 measurements of the tubes in leafstalk and bark obtained. With one or two exceptions the ratio between the tube bore in leafstalk and bark was very constant and the average of 29 relative figures (leafstalk : cortex) was found to be $0{\cdot}686 \pm 0{\cdot}010$ which may be assumed to be the factor for an approximate calculation of the diameter of the latex tubes of the leafstalk from the diameter of those of the cortex.

It has been shown by a number of workers that the correlation between the *yield* and *the number of latex rings in the bark* is not great. In other words the number of latex rings in the bark is not a satisfactory criterion on which to judge the yielding capacity of a tree. Ashplant in his lecture, stated that a better correlation is obtained when the number of productive rings of latex vessels is correlated with the yield. The number of productive

* Dr. A. Frey-Wyssling. Investigation into the relation between the diameter of the latex tubes and the rubber production of *Hevea Brasiliensis* in *Archief voor de Rubber* cultuur Vol. 14, No.3, p.135, March 1930, (English Translation).

rings is obtained by deducting from the total those rings in the area of bark up to 1·6 mm from the cambium, which rings are left untouched in the process of tapping, and also those unproductive rings which are separated from the soft inner bark by the stone cells which are commonly found in the outer bark. It would appear likely also that the girth of the tree affects yield and for that reason the yield per unit length (1 cm) of productive latex row might be expected to give a closer correlation.

In the investigation under discussion the following correlations were obtained :

Correlation between	Yield 1928	Yield 1928 of one productive ring	Yield 1928 of 1 cm. productive ring
Diameter of the latex tubes of the leafstalk	0.54 ± 0.11	0.50 ± 0.14	0.44 ± 0.15
Diameter of the latex tubes of the bark	0.49 ± 0.14	0.41 ± 0.15	0.36 ± 0.16
Number of productive rings of latex tubes	0.75 ± 0.8	—	—

Twenty-nine trees only were used in the investigation from which these figures were obtained. The only correlation coefficient which is significant is that of the correlation between the *number of productive rings of latex tubes and yield* (0·75 ± 0·08). This coefficient is higher than has been obtained by other workers who have correlated the total number of latex rows with yield and will lead to a more accurate selection of high-yielding trees from the examination of latex rows. The absence of correlation between latex tube bore and yield is contrary to the results obtained by Mr. Ashplant.

Dr. Frey-Wyssling has investgated the results still further and has shown that none of the trees with narrow latex tubes are good yielders. That is a distinct point which may affect future selection. On the other hand he has shown that trees with wide latex tubes are not necessarily good yielders. As a result of further investigations he indicates that the structure of the latex tube system and the physiological tendency and condition of certain trees may be responsible for this discrepancy. The conclusion which he draws from his observation is that "A large diameter of the latex tubes is an essential condition for, but unfortunately no proof of a high-yielding tree." In his conclusions for practice he points out that this method of selection would be impracticable for estate practice and that there is no proof that young seedlings possess the tube bore characteristics which they possess at a tappable age. The concluding paragraph of the paper aptly sums up the position and may be quoted. "Unselected plantation seeds would give populations from which the worst yielders could be eliminated according to the diameter test, but at present it is rightly considered antiquated to use such seed as planting material, except for use as budding stocks. In the present state of Hevea selection hardly any benefit can be derived from Ashplant's discovery."—M.P.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 30th APRIL, 1930

Province, &c.	Disease	No. of Cases up to Date since Jan. 1st 1930	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	418	141	48	303	13	54
	Foot-and-mouth disease	221	68	207	10	4	...
	Anthrax	...	...	...	...	...	...
	Piroplasmosis	...	...	...	...	...	...
	Rabies. (Dogs)	...	...	...	...	...	...
Colombo Municipality	Rinderpest	..	...	...	...	...	...
	Foot-and-mouth disease	430	14	415	12	2	1
	Anthrax	1	...	...	1	...	...
	Haemorrhagic septicaemia	3	...	...	3	...	...
	Black Quarter	2	...	...	2	...	...
	Rabies (Dogs)	7	...	...	...	...	7
	Bovine Tuberculosis	1	1	...	1	...	...
Cattle Quarantine Station	Rinderpest	..	...	...	...	...	...
	Foot-and-mouth disease	...	..	...	...	...	...
	Anthrax (Goats)	195*	27	...	195	...	...
Central	Rinderpest	...	..	...	...	...	...
	Foot-and-mouth disease	542	45	487	2	53	...
	Anthrax	1	1	...	1	...	...
	Piroplasmos	4	4	1	3	...	...
	Rabies (Dogs)	1	..	...	...	...	1
Southern	Rinderpest	87	87	9	72	6	...
	Foot-and-mouth disease	259	...	239	6	14	...
	Anthrax	...	...	...	...	...	...
Northern	Rinderpest	...	...	..	...	...	...
	Foot-and-mouth disease	2670	891	2409	70	191	...
	Anthrax	...	...	...	...	...	...
	Black Quarter	49	49	...	49	...	...
Eastern	Rinderpest	...	..	...	...	...	...
	Foot-and-mouth disease	88	...	86	2	...	...
	Anthrax	...	...	...	...	...	...
North-Western	Rinderpest	3210	443	84	2400	2	718
	Foot-and-mouth disease	4	...	4	...	...	...
	Anthrax	...	...	...	..	...	...
	Pleuro-Pneumonia (in Goats) †	50	...		50	...	...
North-Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	1069	...	1045	24	...	...
	Anthrax	...	...	...	...	...	...
Uva	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	72	...	72	...	...	...
	Anthrax	...	...	...	...	...	...
Sabaragamuwa	Rinderpest	57	14	5	51	...	1
	Foot-and-mouth disease	1079	46	1069	7	3	...
	Anthrax	..	...	..	...	...	...
	Haemorrhagic septicaemia	8	...	...	8	...	...
	Rabies (Dogs)	7	7	...	...	...	7

* 1 case in a buffalo

† An outbreak which occurred in March.

G. V. S. Office,
Colombo, 10th May, 1930.

G. W. STURGESS,
Government Veterinary Surgeon.

METEOROLOGICAL REPORT

APRIL, 1930

Station	Temperature				Humidity		Amount of Cloud	Rainfall		
	Mean Maximum	Difference from Average	Mean Minimum	Difference from Average	Day	Night (from Minimum)		Amount	No. of Rainy Days	Difference from Average
	°	°	°	°	%	%		Inches		Inches
Colombo	88·8	+0·7	7·56	+0·1	72	91	7·2	13·52	17	+ 4·86
Puttalam	89·5	+0·4	76·0	+0·8	73	91	5·6	8·40	10	+ 2·95
Mannar	91·4	—0·7	77·7	0	74	89	5·6	3·46	8	+ 0·56
Jaffna	89·4	+0·2	79·6	—0·8	75	87	5·0	1·92	7	— 0·12
Trincomalee	88·0	—1·2	77·4	+0·1	76	89	4·3	2·98	7	+ 0·88
Batticaloa	87·1	—1·3	76·7	+0·8	76	93	5·2	2·35	10	+ 0·43
Hambantota	87·1	—0·2	75·3	+0·6	78	93	5·0	3·04	12	0·29
Galle	87·0	+0·7	76·4	+0·4	79	91	6·4	9·96	19	+ 0·29
Ratnapura	91·9	+2·1	73·9	—0·2	79	93	5·6	12·25	19	— 0·08
A'pura	91·3	—1·7	74·8	+0·6	64	95	6·2	6·68	14	— 0·08
Kurunegala	92·4	+0·4	74·5	+0·3	66	93	6·7	6·87	12	— 3·11
Kandy	88·5	+1·5	70·5	+0·7	67	92	6·2	5·10	13	— 1·74
Badulla	83·9	—0·1	66·4	+0·9	72	97	5·5	4·23	19	— 3·22
Diyatalawa	77·4	0	57·9	—2·2	75	94	6·2	5·88	19	+ 0·11
Hakgala	73·8	—1·4	54·4	+0·5	77	94	5·2	8·54	22	+ 1·31
N'Eliya	71·4	+0·3	48·3	+0·2	74	96	6·5	3·62	19	— 2·04

The rainfall of April was slightly below average at more than half the stations in Ceylon. In most of the cases in which the average was passed, this result was achieved with the help of some heavy rain in the last few days of the month. Stations with more than a couple of inches above average were chiefly along the west coast of the N.W.P., in the W.P., S.P., and Sabaragamuwa (though in each of these provinces deficits were in the majority) and in a group in central Uva. Deficits, though numerous, were for the most part small, not exceeding 5 inches. The highest total for the month was at Hiniduma (28·30") while falls of over 5 inches in a day were recorded at Baddegama (6·16" on the 28th) and at Geekianakanda, Illupalama, Hiniduma and Bandaragama.

Thunderstorm activity though well marked, was below, rather than above, its normal amount for April. The duration of bright sunshine was above average on the west coast and below it on the east.

The first occasion this year on which the wind at Colombo remained in the south-west quadrant throughout the night was on the 27th or about ten days earlier than the corresponding even last year. During a vigorous squall in Colombo on the evening of the 28th, a velocity of 66 miles per hour from the East was recorded at the Pilot Station.

The general indications for the total rainfall from May-September inclusive at the stations on the windward side of the main hills, point to slight excess rather than deficit.

A. J. BAMFORD,
Superintendent, Observatory.